Final Report

Colorado Pikeminnow Habitat Use in the San Juan River, New Mexico and Utah

William J. Miller and Jonathan A. Ptacek
Miller Ecological Consultants, Inc.
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EXECUTIVE SUMMARY

Historically, the Colorado pikeminnow, *Ptychocheilus lucius*, occurred in the mainstem Colorado River and its tributaries from Wyoming to the Gulf of California. The San Juan River in New Mexico and Utah contains a small population of Colorado pikeminnow. The Colorado pikeminnow was listed as a federally endangered species in 1967 (32 Federal Register 4001) and is protected under the provisions of the Endangered Species Act of 1973 (39 Federal Register 1175).

In 1991, The U.S. Fish and Wildlife Service released a Biological Opinion which required seven years of research to be conducted on the San Juan River and it's tributaries. One element of the San Juan River Seven-Year Research Program was to determine habitat requirements of the endangered species found in the San Juan River. The habitat utilization data will be used to fulfill the long range plan objective 5.2, specifically 5.2.5 and 5.2.6 (San Juan River Recovery Implementation Program Biology Committee 1995). The objective of this study was to describe habitat use by adult Colorado pikeminnow during summer months in the San Juan River.

This study determined Colorado pikeminnow habitat use during the summer in the San Juan River, New Mexico and Utah. Although the study area included the entire San Juan River, radio implanted Colorado pikeminnow were only contacted in Reaches 3,4 and 5 for study years 1993 and 1994 and Reaches 5 and 6 for study year 1998. The most downstream contact occurred in 1994 near Bluff, Utah (RM 73.8). The farthest upstream contact was near Farmington, New Mexico (RM 178.8).

Radio implanted fish were intensively tracked to determine both the location within a reach of river and the habitat use by those fish. Radio telemetry was conducted on seven wild adult Colorado pikeminnow that were opportunistically implanted in the spring of 1993 (4 fish) and 1994 (3 fish) with radio transmitters by U.S. Fish and Wildlife Service (Grand Junction, CO) personnel. Seven hatchery-reared Colorado pikeminnow were intensively followed during the summer of 1998.

Any locations where the fish remained for more than 30 minutes were recorded, and if possible, habitat parameters were measured. Data on habitat characteristics near the fish location were acquired by habitat mapping on aerial videography plates and digitizing the habitat maps. Habitat maps were created for each separate fish location during the observation day.

Habitat usage data included a sketch of the habitat surrounding the fish locations and included fish positions marked on the map. Data collected at the fish location included date, time of day, weather conditions, time monitored, and any notes on movement during the observation period. When possible, other physical habitat data was collected at each fish location. These measurements included water depth, water velocity (mean column and bottom), substrate type, proximity to cover, description of cover at the location, general description of the site; measurements of the habitat type including

length, width, bank features, shoreline vegetation, dominant substrate and cover for the habitat type. Other parameters measured included water and ambient air temperature, conductivity, and pH. Discharge was obtained from the nearest USGS gaging station.

Radio telemetry studies on Colorado pikeminnow provided seasonal habitat use, river reach use, and spawning behavior for San Juan River fish. These studies also identified possible spawning areas. The majority of wild Colorado pikeminnow contacts were between RM 120.0 and RM 142.0. Only one fish was located outside of this range. Ryden and Ahlm (1996) also found Colorado pikeminnow to be concentrated within this section of the San Juan River. Three of the stocked Colorado pikeminnow were also found in this area, although all three of the transmitters were eventually recovered. It is unknown whether the fish expelled the transmitters or died. Generally, stocked Colorado pikeminnow did not behave like the wild fish monitored in 1993 and 1994. Only the stocked Colorado pikeminnow 40.051 exhibited behaviors and habitat use similar to a wild fish.

Habitat use during the suspected spawning period is concentrated in areas of very diverse habitats with numerous habitat types present. These areas are located in conjunction with complex bar and island systems that have many different habitat types in a small local area. Main features present at the suspected spawning areas include eddies or pools as resting habitat located in close proximity to chutes or steep riffles with very loose cobble substrate.

Two (RM 131.1 and RM 132.0) potential spawning locations were identified for wild fish and one (RM 168.4) for stocked Colorado pikeminnow. One of those locations had a documented visual sighting of two paired Colorado pikeminnow, male and female, that were implanted with radio transmitters. The potential sites at RM 131.1 and RM 132.0 were used during both 1993 and 1994 and were used in the same sequence each year. The uppermost site at RM 132.0 was used first followed by the RM 131.1 site.

The use of various habitat types is related to the flow regime as well as life history traits of the Colorado pikeminnow. The pre-spawn time period is during the ascending limb of runoff, which floods local embayments, tributary mouths and secondary channels that provide Colorado pikeminnow staging habitat. During the descending limb of runoff, the habitat complexes for spawning become available, provided sufficient cleaning is done during the peak runoff. These habitats appear to be used for varying lengths of time depending on the suitability of velocities in chute/riffle habitats and the embeddedness of cobble substrate.

Maintaining habitat richness is an important component of maintaining the potential spawning habitats for the fish. Highest habitat use during the spawning periods was in the area of highest habitat richness. Flows that develop and maintain complex habitats over the long term should provide the physical characteristics necessary to provide the spawning habitat.

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INTRODUCTION

Historically, the Colorado pikeminnow, *Ptychocheilus lucius*, occurred in the mainstem Colorado River and its tributaries from Wyoming to the Gulf of California. The San Juan River in New Mexico and Utah contains a small population of Colorado pikeminnow. The Colorado pikeminnow was listed as a federally endangered species in 1967 (32 Federal Register 4001) and is protected under the provisions of the Endangered Species Act of 1973 (39 Federal Register 1175).

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Researchers have been studying movement and habitat use of Colorado pikeminnow since the mid 1970s (Twedt and Holden 1980; Holden and Wick 1982; Wick et al. 1983, 1986; Tyus and McAda 1984; Osmundson and Kaeding 1989). The focus of these previous research efforts has been either long range spawning migrations or intensive study of localized habitat use. Researchers have found that Colorado pikeminnow habitat use varies seasonally and by habitat availability (Holden and Wick 1982; Wick et al. 1983; Tyus and McAda 1984; Osmundson et al. 1995). However, none of these previous studies were conducted on the San Juan River.

During spring runoff, many native fish species (including Colorado pikeminnow) utilize backwater habitats as refuge from high flows (Wick et al. 1983, 1986; Tyus and McAda 1984; Osmundson and Kaeding 1989; Tyus 1990). Water temperatures are higher in backwaters, providing better conditions for growth and gonad maturation (Wick et al. 1983, 1986; Osmundson and Kaeding 1989; Tyus 1990). Osmundson and Kaeding (1989) observed a high use of backwaters by adult Colorado pikeminnow during spring and early summer in the upper Colorado River. They recorded temperatures in backwater areas up to 10.5°C warmer than in the main channel. In the Green River subbasin, (Tyus 1990) reported high usage of backwater and flooded bottomlands in the Green and Yampa rivers. Colorado pikeminnow were most often found in to backwaters in low-water years and flooded bottomlands in high water years. Holden and Stalnaker (1975) found adult pikeminnow in all habitat types but mainly in slow velocity habitats (eddies, backwaters, and flooded canyon mouths). Tyus and McAda (1984) reported that adult Colorado pikeminnow predominately used shoreline habitats associated with sandy substrate. They also noted use of eddy, run, backwater, and pool habitats and silt, boulder, rubble, and gravel substrates.

There were significant differences between rivers for water depths and velocities selected by the fish. In the '15 mile reach' of the Colorado River near Grand Junction, Colorado, run habitats were most often used by Colorado pikeminnow during the summer (Osmundson and Kaeding 1989; Osmundson et al. 1995). These researchers also noted that Colorado pikeminnow sought deep water when water clarity was high. Tyus and Karp (1989) reported that adult Colorado pikeminnow occupied a variety of habitats in mid-to-late summer, but were most common in eddies, pools, runs, and shoreline backwaters. Wick et al. (1983) noted a high use of runs during the summer and pool habitat during October and November on the Yampa River. However, Miller and Rees (1997) found that adult pikeminnow in the Yampa River used predominately pool habitat from late July through October.

During the winter, Wick and Hawkins (1989) and Valdez and Masslich (1991) observed Colorado pikeminnow utilizing embayment, backwater, and run habitats in the Yampa and Green rivers. Valdez and Masslich (1991) noted that wintering pikeminnow were often associated with an instream cover element (e.g. sand shoals, sand ridges, cobble jetties, or ice jams). They reported that Colorado pikeminnow preferred areas of low velocity (0.0-0.15 m/sec) and moderate depths (0.6-1.1 m) during wintertime monitoring.

Wick et al. (1986) censused habitat types (pools, eddies, and backwaters) on the Yampa River during spring runoff and base flows. They reported a strong relationship between the quantity and quality of habitat and the number of pikeminnow captured during the daytime. Several studies have found pikeminnow to be more abundant in higher diversity habitats than in lower diversity habitats (Wick et al. 1986; Osmundson and Kaeding 1991). Wick et al. (1986) found at base flows, the strata with the highest amount of class 1 (> 2 m maximum depth) pools and eddies (n=1.7, area = 5900 m^2 per mile) contained 51% (total n = 74) of the pikeminnow captured. The existing information on pikeminnow habitat use in the San Juan River includes habitat suitability criteria developed for the San Juan River from habitat use information from other rivers in the upper Colorado River basin (Twedt and Holden 1980).

METHODS

Study Area

Seven-Year Research Program

The San Juan River is a major tributary of the Colorado River and drains 99,200 km^2 in Colorado, Utah, Arizona, and New Mexico (Figure 1). From its origins in the San Juan Mountains of southwestern Colorado at elevations exceeding 4,250 m, the river flows westward for about 570 km to the Colorado River. The major perennial tributaries to the San Juan River are the Navajo, Piedra, Los Pinos, Animas, La Plata, and Mancos rivers, and McElmo Creek. In addition there are numerous ephemeral arroyos and washes contributing little total flow but large sediment loads.

Navajo Reservoir, completed in 1963, impounds the San Juan River, isolating the upper 124 km of river and partially regulating downstream flows. The completion of Glenn Canyon Dam and subsequent filling of Lake Powell in the early 1980's inundated the lower 87 km of the river, leaving about 359 km of river between the two bounding features.

From Navajo Dam to Lake Powell, the mean gradient of the San Juan River is 1.67 m/km. Locally, the gradient can be as high as 3.5 m/km, but taken in 30 km increments, the range is from 1.24 to 2.41 m/km. Between the San Juan River mouth into Lake Powell and the confluence with Chinle Creek about 20 km downstream of Bluff, UT, the river is canyon bound and restricted to a singled channel. Upstream of Chinle Creek the river is multi-channeled to varying degrees with the highest density of secondary channels between the Hogback Diversion about 13 km east of Shiprock and Bluff, Utah. The reach of river between Navajo Dam and Farmington, NM is relatively stable with predominantly embedded cobble substrate and few secondary channels. Below the confluence with the Animas River, the channel is less stable and more subject to floods from the unregulated Animas River. Between Farmington and Shiprock cobble substrate still dominates, although it is less embedded. Between Shiprock and Bluff the cobble substrate becomes mixed with sand to an increasing degree with distance downstream, resulting in decreasing channel stability.

Except in canyon-bound reaches, the river is bordered by nonnative salt cedar (*Tamarix chinensis*) and Russian olive (*Eleagnus angustifolia*) and native cottonwood (*Populas fremonti*) and willow (*Salix* sp.). Nonnative woody plants are most abundant with cottonwood and willow accounting for less than 15% of the riparian vegetation.

Discharge of the San Juan River is typical of rivers in the American Southwest. The characteristic annual pattern is one of large flows during spring snowmelt, followed by low summer, autumn, and winter base flows. Base flows are frequently punctuated by convective storm-induced flow spikes during summer and early autumn. Prior to closure of Navajo Dam about 73% of the total annual discharge (based on USGS Bluff, Utah

gage) of the drainage occurred during spring runoff (1 March through 31 July). The median daily peak discharge during spring runoff was 10,400 cfs (range = 3,810 to 33,800 cfs). Although flows resulting from summer and autumn storms contributed a comparatively small volume to total annual discharge in the basin, the magnitude of storm-induced flows exceeded the peak snowmelt discharge about 30% of the years, occasionally exceeding 40,000 cfs (mean daily discharge). Both magnitude and frequency of these storm induced flow spikes are greater than those seen in the Green or Colorado rivers.

Closure of Navajo Dam altered the annual discharge pattern of the San Juan River. The natural flows of the Animas River ameliorated some aspects of regulated discharge by augmenting spring discharge. Regulation resulted in reduced magnitude and increased duration spring runoff in wet years and seriously reduced magnitude and duration spring flows during dry years. Overall, flow regulation by operation of Navajo Dam has resulted in post-dam peak spring discharge averaging about 54% of pre-dam values. After dam closure, base flows were increased substantially over pre-dam base flows.

Since 1992, Navajo Dam has been operated to mimic a "natural" hydrograph with the volume of release during spring linked to the amount of precipitation during the preceding winter. Thus in years with high spring snowmelt, reservoir releases were "large" and "small" in low runoff years. Base flows since 1992 were typically greater than during pre-dam years but less than post-dam years.

The primary study area for most studies conducted under the auspices of the San Juan River Seven-Year Research Program, including that reported herein, were accomplished in the mainstem San Juan River and its immediate vicinity between Navajo Dam and Lake Powell. Between Navajo Dam and Shiprock there is considerable human activity within the floodplain of the San Juan River. Irrigated agriculture is practiced throughout this portion of the valley and much of the immediate uplands. Much of the river valley not devoted to agriculture (crop production and grazing) consists of small communities (e.g. Blanco and Kirtland) and several larger towns (e.g. Bloomfield and Farmington). The valley of the Animas River, the San Juan's largest tributary in the study area, is similarly developed. Downstream of Shiprock to Bluff small portions of the river valley (and uplands) are farmed; dispersed livestock grazing is the primary land use. In the vicinity of Montezuma Creek and Aneth, petroleum extraction occurs within the floodplain and the adjacent uplands. Between Bluff and the confluence with Lake Powell, there are few human-caused modifications of the system.

To enhance comparisons among studies and to provide a common reference for all research, a multivariate analysis of a variety of geomorphic features of the drainage was performed to segregate the river into distinct geomorphic reaches. This effort (Bliesner and Lamarra, 1999) identified eight reaches between Navajo Dam and Lake Powell. The following provides a brief characterization of each reach.

Reach 1 (RM 0 to 16, Lake Powell confluence to near Slickhorn Canyon) has been heavily influenced by the fluctuating reservoir levels of Lake Powell and its backwater

effect. Fine sediment (sand and silt) has been deposited to a depth of about 12 m in the lowest end of the reach since the reservoir first filled in 1980. This deposition of suspended sediment into the delta-like environment of the river/reservoir transition has created the lowest-gradient reach in the river. This reach is canyon bound with an active sand bottom. Although there is an abundance of low velocity habitat at certain flows, it is highly ephemeral, being influenced by both river flow and the elevation of Lake Powell.

Reach 2 (RM 17 to 67, near Slickhorn Canyon to confluence with Chinle Creek) is also canyon bound but is located above the influence of Lake Powell. The gradient in this reach is higher than in either adjacent reach and the fourth highest in the system. The channel is primarily bedrock confined and is influenced by debris fans at ephemeral tributary mouths. Riffle-type habitat dominates, and the major rapids in the San Juan River occur in this reach. Backwater abundance is low in this reach, occurring most in association with the debris fans

Reach 3 (RM 68 to 105, Chinle Creek to Aneth, Utah) is characterized by higher sinuosity and lower gradient (second lowest) than the other reaches, a broad floodplain, multiple channels, high island count, and high percentage of sand substrate. This reach has the second highest density of backwater habitats after spring peak flows, but is extremely vulnerable to change during summer and autum storm events, after which this reach may have the second lowest density of backwaters. The active channel leaves debris piles deposited throughout following spring runoff, leading to the nickname "Debris Field".

Reach 4 (RM 107 to 130, Aneth, Utah, to below "the Mixer") is a transitional reach between the upper cobble-dominated reaches and the lower sand-dominated reaches. Sinuosity is moderate compared with other reaches, as is gradient. Island area is higher than in Reach 3 but lower than in Reach 5, and the valley is narrower than in either adjacent reach. Backwater habitat abundance is low overall in this reach (third lowest among reaches) and there is little clean cobble.

Reach 5 (RM 131 to 154, the "Mixer" to just below Hogback Diversion) is predominantly multi-channeled with the largest total wetted area (TWA) and largest secondary channel area of any of the reaches. Secondary channels tend to be longer and more stable than in Reach 3 but fewer in number overall. Riparian vegetation is more dense in this reach than in lower reaches but less dense than in upper reaches. Cobble and gravel are more common in channel banks than sand, and clean cobble areas are more abundant than in lower reaches. This is the lowermost reach containing a diversion dam (Cudei). Backwaters and spawning bars in this reach are much less subject to perturbation during summer and fall storm events than the lower reaches.

Reach 6 (RM 155 to 180, below Hogback Diversion to confluence with the Animas River) is predominately a single channel, with 50% fewer secondary channels than Reaches 3, 4, or 5. Cobble and gravel substrates dominate, and cobble bars with clean interstitial space are more abundant in this reach than in any other. There are four diversion dams that may impede fish passage in this reach. Backwater habitat abundance

is low in this reach, with only Reach 2 having less. The channel has been altered by dike construction in several area to control lateral channel movement and over-bank flow.

Reach 7 (RM 181 to 213, Animas River confluence to between Blanco and Archuleta, New Mexico) is similar to Reach 6 in terms of channel morphology. The river channel is very stable, consisting primarily of embedded cobble substrate as a result of controlled releases from Navajo Dam. In addition, much of the river bank has been stabilized and/or diked to control lateral movement of the channel and over-bank flow. Water temperature is influenced by the hypolimnetic release from Navajo Dam and is colder during the summer and warmer in the winter than the river below the Animas confluence.

Reach 8 (RM 213 to 224, between Blanco and Archuleta and Navajo Dam) is the most directly influenced by Navajo Dam, which is situated at its uppermost end (RM 224). This reach is predominantly a single channel, with only four to eight secondary channels, depending on the flow. Cobble is the dominant substrate type, and because lateral channel movement is less confined in this reach, some loose, clean cobble sources are available from channel banks. In the upper end of the reach, just below Navajo Dam, the channel has been heavily modified by excavation of material used in dam construction In addition, the upper 10 km of this reach above Gubernador Canyon are essentially sediment free, resulting in the clearest water of any reach. Because of Navajo Dam, this area experiences much colder summer and warmer winter temperatures. These cool, clear water conditions have allowed development of an intensively managed blue-ribbon trout fishery to the exclusion of the native species in the uppermost portion of the reach.

Colorado Pikeminnow Habitat Use Study

This study determined Colorado pikeminnow habitat use during the summer in the San Juan River, New Mexico and Utah. Although the study area included the entire San Juan River, radio implanted Colorado pikeminnow were only contacted in Reaches 3,4 and 5 for study years 1993 and 1994 and Reaches 5 and 6 for study year 1998. The most downstream contact occurred in 1994 near Bluff, Utah (RM 73.8). The farthest upstream contact was near Farmington, New Mexico (RM 178.8). This is the location where the stocked pikeminnow were released in September 1997.

Radio Telemetry

Radio implanted fish were intensively tracked to determine both the location within a reach of river and the habitat use by those fish. Seven wild adult Colorado pikeminnow were opportunistically implanted in the spring of 1993 (4 fish) and 1994 (3 fish) with radio transmitters by U.S. Fish and Wildlife Service (Grand Junction, CO) personnel (Table 1). On 23 September 1997, 15 hatchery-reared Colorado pikeminnow were implanted with radio tags and released (Table 1). Seven of the fifteen stocked fish were located during the summer of 1998. The remaining eight radio tags were either recovered or presumed lost.

Table 1. San Juan River Colorado pikeminnow radio frequencies and capture or stock locations.

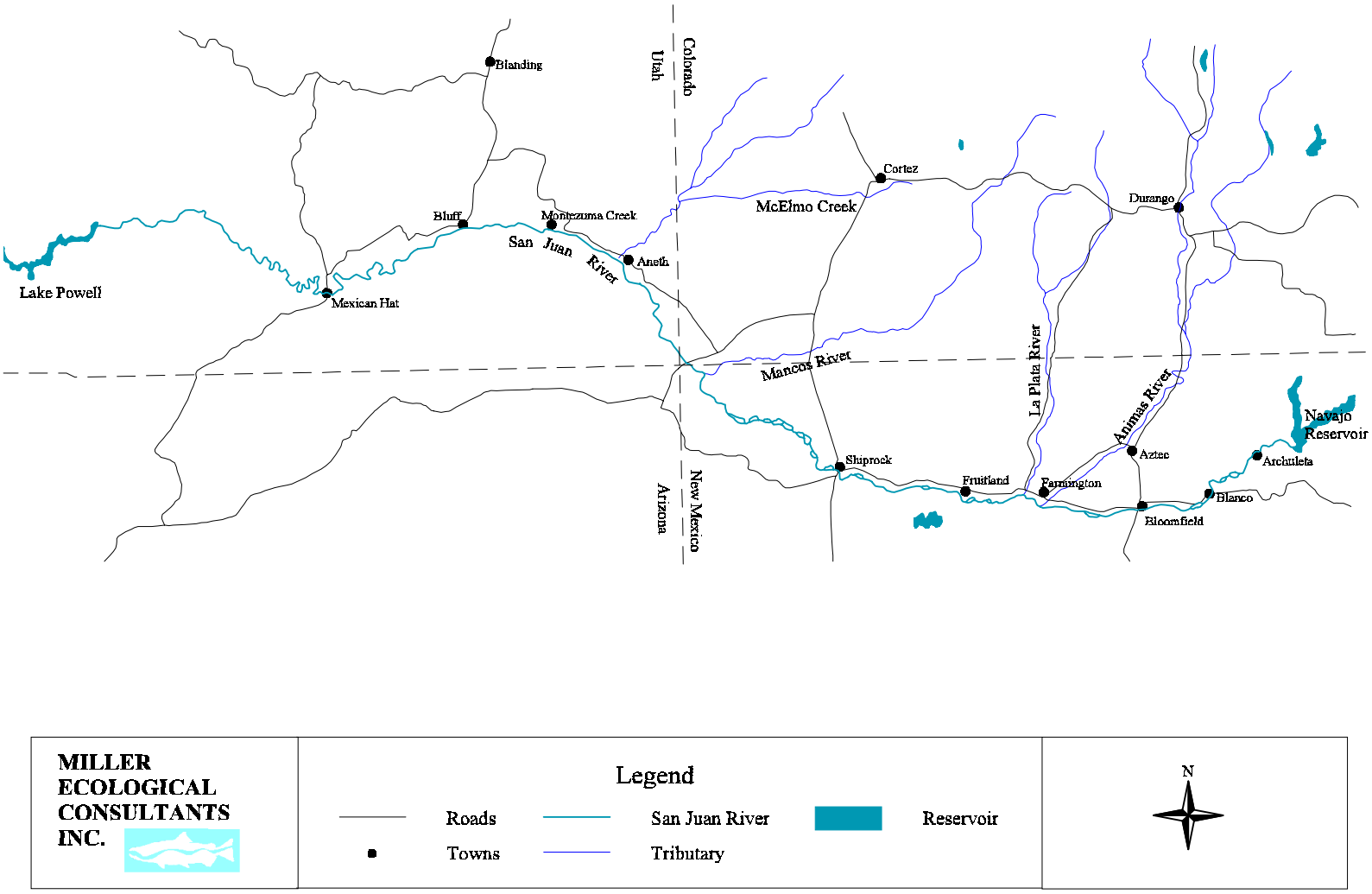
Frequency	Capture (1993-1994) or Stock (1997) Information Date	River Mile	Years Monitored	Sex	TL (mm)	SL (mm)	Weight (g)
40.030	5/15/93	122.05	1993,1994	F	764	643	4760
40.100	4/14/93	126.25	1993	F	948	820	8050
40.200	4/13/93	130.6	1993	M	521	445	1200
40.848/980	4/14/93	128.8	1993,1994	F	797	685	5550
40.280	4/15/94	133.00	1994	M	617	510	2000
40.848/980	4/12/94	128.60	1993,1994	F	820	695	5810
40.910	5/16/94	74.70	1994	F	759	630	4000
40.940	4/14/94	122.60	1994	F	754	628	4450
40.020*	9/23/97	178.8	1998	M	580		1326
40.030	9/23/97	178.8	1998	F	698		2238
40.040*	9/23/97	178.8	1998	F	734		2410
40.051*	9/23/97	178.8	1998	F	753		3100
40.060	9/23/97	178.8	1998	F	660		1825
40.070*	9/23/97	178.8	1998	F	707		2502
40.080	9/23/97	178.8	1998	F	703		2110
40.090	9/23/97	178.8	1998	F	629		1583
40.100	9/23/97	178.8	1998	F	650		1848
40.110*	9/23/97	178.8	1998				
40.120	9/23/97	178.8	1998	F	745		2933
40.130*	9/23/97	178.8	1998	F	641		1582
40.140	9/23/97	178.8	1998	F	734		2700
40.600	9/23/97	178.8	1998	F	698		2067
40.611	9/23/97	178.8	1998	F	742		2910
40.780*	9/23/97	178.8	1998	F	671		2435

Note: An asterisk (*) denotes stocked pikeminnow monitored during the summer of 1998. All 1997 fish are hatchery origin.

Radio tracking was conducted for five consecutive days each observation week. One fish was selected to be monitored for a continuous twenty-four hour period each week.

During the 1993 and 1994 study years, each day scheduled for observation was divided into four observation periods. Each observation period was six hours long and determined by sunrise and sunset. Time periods were numbered as follows: Period 1 - three hours before to three hours after sunrise; Period 2 - three hours after sunrise to three hours before sunset; Period 3 - three hours before sunset to three hours after sunset; and Period 4 - three hours after sunset to three hours before sunrise.

Figure 1. Study Area Map.



Observations were made during Periods 1 and 3 every day of a scheduled observation week. A random selection process was used to determine which fish was observed during Period 1 and 2. Limited observations were made during Period 4. In 1998, observed fish were not randomly selected or related to time period due to widespread fish distribution and access constraints. In all years selected fish were successfully located and generally monitored for two hours.

Radio telemetry was conducted using an Advanced Telemetry Systems (ATS) programmable receiver and a directional antenna. To determine approximate fish locations, aerial surveys using a wing-mounted directional antenna were conducted at the beginning of the summer observations 1993, 1994 and 1998. Ground contact surveys began immediately after the air surveys to confirm fish locations. Fish locations in the river were obtained during ground surveys by walking the shoreline or floating the river.

After signal contact was made, the crew would determine the fish position using a triangulation method from positions along the shore. Whenever possible, the crew would obtain a strong signal and a null at a location upstream of the fish location, then the crew would move to a position directly across from the fish and obtain a second null signal. The fish position was the intersection point on the lines from the two null signals. Usually this location was verified by obtaining third null signal at a downstream location. At times, fish position or topography inhibited this procedure. In those instances, fish position was estimated from at least one shore or boat position.

Any locations where the fish remained for more than 30 minutes were recorded, and if possible, habitat parameters were measured. Data on habitat characteristics near the fish location were acquired by habitat mapping on aerial videography plates and digitizing the habitat maps. Bureau of Indian Affairs (1993 and 1994) or Ecosystems Research Institute (1998) personnel were responsible for the onstream habitat mapping. Habitat maps were created for each separate fish location during the observation day.

Habitat usage data included a sketch of the habitat surrounding the fish locations and included fish positions marked on the map. Habitat was classified with the same system used for the quantification of habitat availability (Table 2, see Bliesner and Lamarra (1995)). Data collected at the fish location included date, time of day, weather conditions, time monitored, and any notes on movement during the observation period. When possible, other physical habitat data was collected at each fish location. These measurements included water depth, water velocity (mean column and bottom), substrate type, proximity to cover, description of cover at the location, general description of the site; measurements of the habitat type including length, width, bank features, shoreline vegetation, dominant substrate and cover for the habitat type. Other parameters measured included water and ambient air temperature, conductivity, and pH. Discharge was obtained from the nearest USGS gaging station.

Telemetry data was divided into pre-spawn (May-June), spawn (July) and post-spawn (August) periods. Period break-lines were based upon observed behaviors of Colorado pikeminnow in the San Juan River during the study years. Observations were analyzed

Table 2. Habitat categories used during monitoring.

Habitat Number	Habitat Type	Habitat Number	Habitat Type	Habitat Number	Habitat Type
1	Backwater	11	Scour Run	26	Rootwad Pool
2	Backwater Pool	12	Shore Run	27	Abandoned Channel
3	Pool	13	Undercut Run	28	Sand Bar
4	Debris Pool	14	Run/Riffle	29	Tributary
5	Rootwad Pool	15	Riffle	30	Shoal/Riffle
6	Eddy	16	Riffle Eddy	31	Island
7	Edge Pool	17	Shore Riffle	32	Rapid
8	Shoal	18	Riffle/Chute	33	Irrigation Return
8a	Sand Shoal	19	Chute	34	Inundated Veg.
8b	Cobble Shoal	20	Slackwater	35	Pocket Water
9	Shoal/Run	21	Isolated Pool	36	Boulders
9a	Sand Shoal/Run	22	Embayment	37	Waterfall
9b	Cobble Shoal/Run	24	Overhanging Veg.		
10	Run	25	Cobble Bar		

for 1993, 1994, 1993 and 1994 combined, and 1998. Observations from 1998 were not combined with 1993 and 1994 data because the 1998 monitored fish were hatchery-reared. Gross movement (difference between most upstream location and farthest downstream location), and daily movement were calculated. These parameters will be reported in miles because contact locations were recorded by river mile. Habitat maps were digitized into Arcview version 3.1 and the areas of individual habitats were calculated. Areas of each habitat type, including the habitat with the fish location were used to develop total available habitat within a specific reach of stream. Habitat richness was measured by averaging the number of unique habitat types per habitat mapping plate. Richness was calculated for pre-spawn, spawn, and post-spawn telemetry periods.

Habitat selectivity was determined by the comparison of habitat usage to habitat availability (Swanson et al. 1974; Johnson 1980). Selectivity for a habitat type occurs if the percent of time that radio implanted fish were monitored in that habitat type is greater than the percent of the total habitat area that the particular habitat type accounted for. If no selectivity occurred then all habitats should be used in the same proportion as they occur within the system. Low numbers of monitored pikeminnow and small numbers of contacts for individual fish precluded the use of the methodology used by Osmundson et al. (1995) and Ryden (1999) for the quantification of habitat selectivity.

RESULTS

1993

Intensive radio tracking of Colorado pikeminnow was conducted for 30 days during the period from 21 June 1993 through 13 August 1993. Radio frequencies for the four Colorado pikeminnow monitored during 1993 were 40.030, 40.100, 40.200, and 40.848. Length, weight, sex and river mile capture information are located in Table 1. One Colorado pikeminnow captured in 1993 was implanted with tag 40.980, upon its recapture in 1994, it was implanted with radio tag 40.848. Results from 1993 and 1994 for this fish are presented using the 1994 transmitter frequency 40.848.

All radio implanted fish remained upstream of RM 122.6 during the 1993 study period. The four radio implanted fish had an average gross movement of 8.0 mi during the 1993 monitoring. Colorado pikeminnow 40.848 had the largest gross movement (11.00 mi), while fish 40.200 had the least with 2.28 mi (Table 3). Fish 40.030 and 40.100 moved 9.25 and 9.45 mi, respectively.

The localized movement within and between habitat types resulted in relatively short distances moved during each day (Table 4). Implanted fish had the least localized movement from 26 July – 30 July 1993, averaging only 3.6 m of movement during monitoring (Table 4). Radio implanted fish moved more than one river mile in a day on four occasions (Table 5). During the 1993 monitoring period radio implanted fish spent the majority of time in run (43.0%), eddy (25.5%), and run/riffle (11.9%) habitats (Figure 2). Radio implanted fish were found in 11 different habitat types and individual fish used an average of 5.5 habitats. Overall, eddy habitat had the highest selectivity, although radio implanted fish also showed some selectivity for backwater, edge pool, slackwater, undercut run, run/riffle and chute habitats (Figure 3). Habitat richness was highest during the spawning period followed by the post-spawn period (Table 6).

Table 3. River mile locations for monitored Colorado pikeminnow, June – August 1993. Multiple contact times (24 hr) are in parentheses.

	Fish Frequency			
Date	**40.030**	**40.100**	**40.200**	**40.848**
6/21/93			131.90	
6/22/93	122.60		130.80	
6/23/93		122.8 (0845)	130.80	
6/23/93		123.10 (1045)		
6/24/93	122.60	122.60		137.70
6/25/93	122.60	122.60		
6/28/93				137.30
6/29/93		122.60		
6/30/93		122.60		137.30
7/1/93	122.60 (0800)	123.40		137.30
7/12/93		132.05 (1430)	132.00	132.00
7/12/93		132.00 (1500)		
7/13/93			132.00	132.00 (0740)
7/13/93				131.15 (1645)
7/14/93			132.00 (0740)	131.15 (1010)
7/14/93			132.01 (1730)	131.00 (1850)
7/15/93			131.50 (0815)	
7/15/93			131.40 (1200)	
7/15/93			131.60 (1800)	
7/15/93			132.00 (2010)	
7/15/93			132.02 (2300)	
7/16/93			132.02 (0000)	
7/16/93			132.15 (0150)	
7/16/93			132.08 (0600)	
7/19/93	131.01 (1545)		131.15	
7/19/93	131.06 (1730)			
7/20/93	131.15		131.15	
7/21/93	130.30 (1845)		131.15	141.30
7/21/93	130.48 (2200)			
7/22/93	130.30 (0815)		131.15 (1035)	
7/22/93	130.65 (1140)			
7/26/93	128.83			
7/27/93			131.40	
7/28/93			131.40	141.95
7/29/93	128.10		131.15	
7/30/93				141.30
8/9/93	131.85		131.15	
8/10/93	131.85 (0910)		131.15 (1200)	
8/10/93	131.60 (1055)		129.80 (1830)	
8/11/93	131.40		131.15	142.00
8/12/93				142.00 (1015)
8/12/93				141.85 (2220)
8/13/93				141.65 (0645)
8/13/93				141.85 (0815)
Movement	**40.030**	**40.100**	**40.200**	**40.848**
MIN (RM)	122.60	122.60	129.80	131.00
MAX (RM)	131.85	132.05	132.08	142.00
GROSS (mi)	9.25	9.45	2.28	11.00

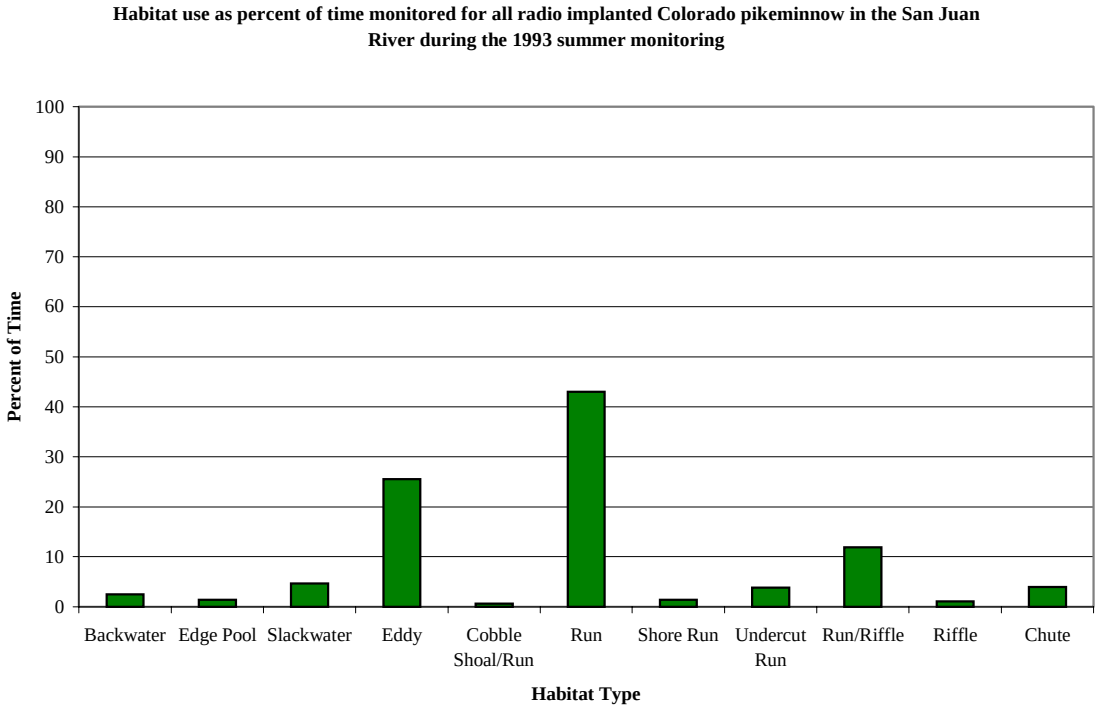
Table 4. Distance (m) moved upstream or downstream by Colorado pikeminnow during daily monitoring in the San Juan River, June – August 1993.

	Fish Frequency			
Date	**40.030**	**40.100**	**40.200**	**40.848**
6/21/93			9	
6/22/93	6		966	
6/23/93		510	12	
6/24/93	9	9		5
6/25/93	11	11		
6/28/93				30
6/29/93		6		
6/30/93		6		40
7/1/93	521	0		87
7/2/93	35			
7/12/93		134	0	0
7/13/93			3	49
7/14/93			9	15
7/15/93			685	
7/16/93			0	
7/19/93	76		0	
7/20/93	12		8	
7/21/93	835		35	73
7/22/93			76	
7/26/93	6		6	
7/27/93			5	
7/28/93			6	0
7/29/93	0		6	
7/30/93				0
8/9/93	18		8	
8/10/93	468		457	
8/11/93	6		0	46
8/12/93				326
8/13/93				805

Table 5. Distance (mi) moved between the first and last daily contact of monitored Colorado pikeminnow, June – August 1993.

	Fish Frequency			
Date	**40.030**	**40.100**	**40.200**	**40.848**
6/21/93			0	
6/22/93	0		0	
6/23/93		0.3	0	
6/24/93	0	0		0
6/25/93	0	0		
6/28/93				0
6/29/93		0		
6/30/93		0		0
7/1/93	0	0		0
7/2/93	0			
7/12/93		0.05	0	0
7/13/93			0	0.85
7/14/93			0.10	0.14
7/15/93			0.87	
7/16/93			0.07	
7/19/93	0.05		0	
7/20/93	0		0	
7/21/93	1.38		0	0
7/22/93			0	
7/26/93	0		0	
7/27/93			0	
7/28/93			0	0
7/29/93	0		0	
7/30/93				0
8/9/93	0		0	
8/10/93	0.3		1.35	
8/11/93	0		0	0
8/12/93				0.16
8/13/93				0.55

Figure 2. Habitat use as a percent of time monitored during the summer 1993.



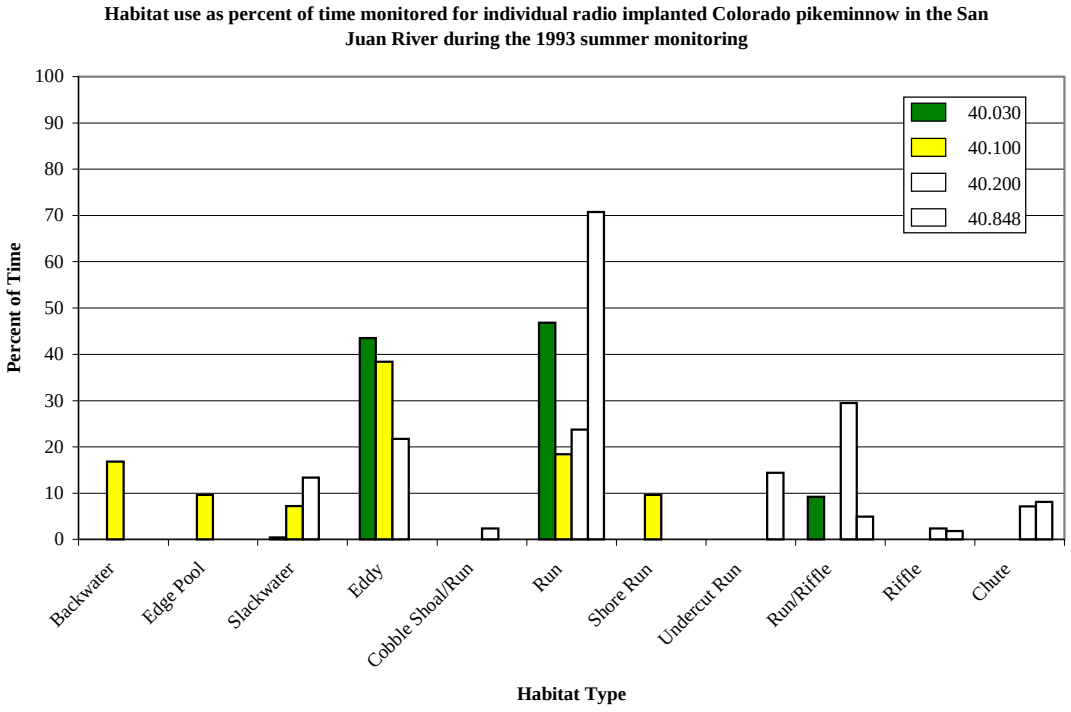


Figure 3. Habitat usage and habitat availability as a percent of total during the summer 1993.

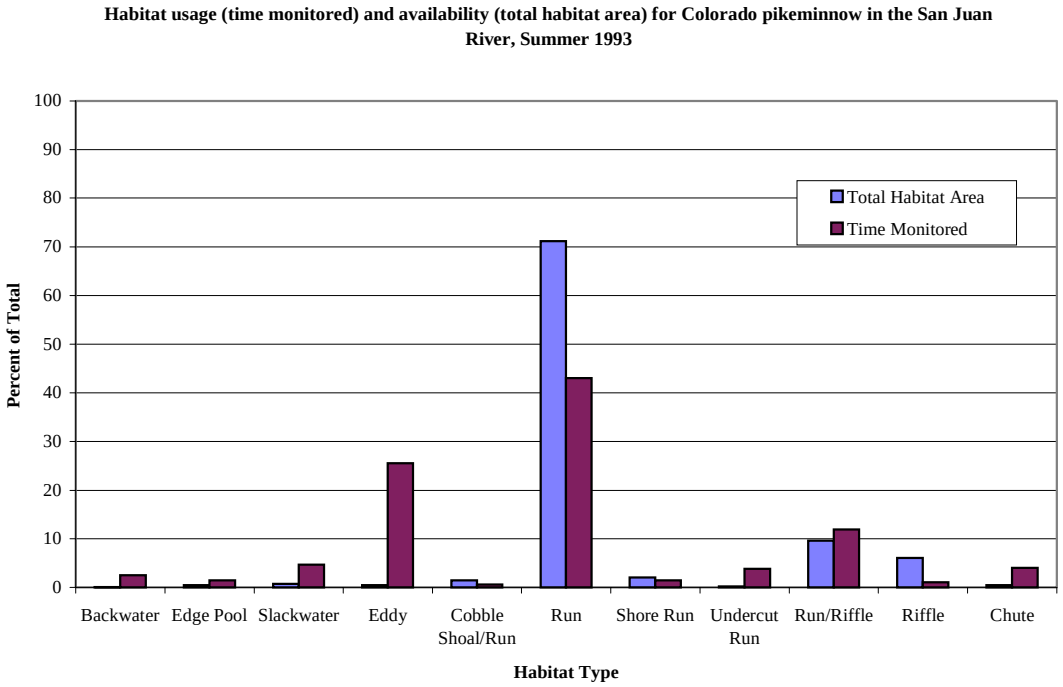


Table 6. Habitat richness values for Colorado pikeminnow locations during 1993, 1994, 1993 and 1994 combined and 1998 on the San Juan River.

	Study Year			
Period	1993	1994	1993/1994	1998
Pre-spawn	5.15	4.64	4.92	4.67
Spawn	5.92	4.78	5.13	9.00
Post-spawn	5.44	n/a	5.44*	n/a
Summer	5.63	4.76	5.11	7.70
Fall		6.67		
Winter		6.30		

Note: Telemetry was not conducted during the post-spawn period in 1994.

Pre-spawn

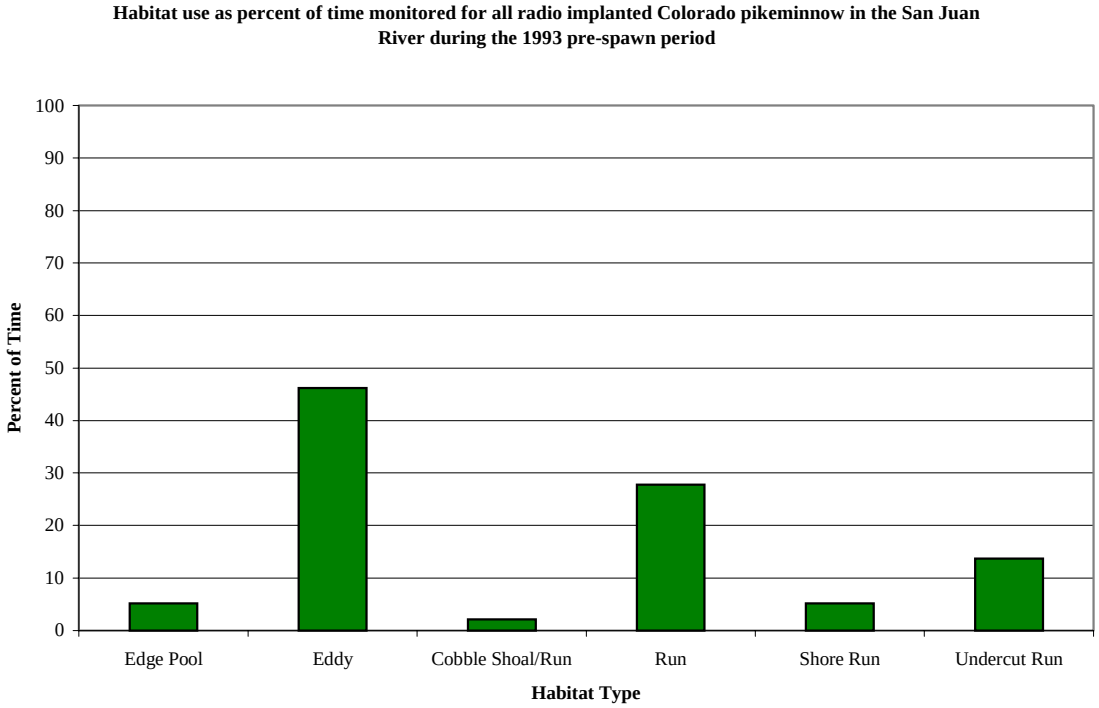
Radio implanted fish were widely separated during most of the pre-spawn period. Fish 40.030 and 40.100 used the area around the Mancos River confluence (RM 122.6), while fish 40.200 was found near RM 131. Fish 40.848 was found at RM 137.3 - the farthest upstream location of any fish monitored in 1993 (Table 3). Habitat types used included main channel eddies, side-channels and the Mancos River confluence. Water temperatures in these side-channels and Mancos River confluence were approximately two to four degrees warmer than main channel habitats for the same dates (Table 7).

Radio implanted pikeminnow used eddy habitat most often, spending over 45% of the total time in that habitat (Figure 4). Run, undercut run, edge pool and shore run accounted for 27.8%, 13.7%, 5.1%, and 5.1% of the time monitored, respectively. Individually, fish 40.030 and 40.100 spent the majority of the pre-spawn period in eddy habitat (Figure 4). Fish 40.848 spent the most time in run habitat, although this fish also utilized undercut run habitat (Figure 4). Colorado pikeminnow 40.848 and 40.200 did not use eddy habitat. Radio implanted fish in the pre-spawn period had a high selectivity for eddy habitat and to a lesser extent for edge pool (Figure 5).

Table 7. Water temperatures (C^0) for pikeminnow locations during the pre-spawn 1993 and 1994 where main channel and side channel or tributary temperatures were concurrently taken.

Date	Fish Frequency	River Mile	Water Temperature (C^0)	
			Side channel, tributary	Main channel
6/22/93	40.200	130.8	17.2	15.0
6/24/93	40.100, 40.030	122.6	17.2	13.9
6/25/93	40.030	122.6	16.7	13.3
6/29/93	40.100	122.6	20.0	15.6
6/30/93	40.100	122.6	18.3	15.6
6/03/94	40.940	122.6	17.8	13.3
6/17/94	40.940	122.6	15.6	13.3
6/20/94	40.030	122.6	20.6	17.2

Figure 4. Habitat use as a percent of time monitored during the pre-spawn period 1993.



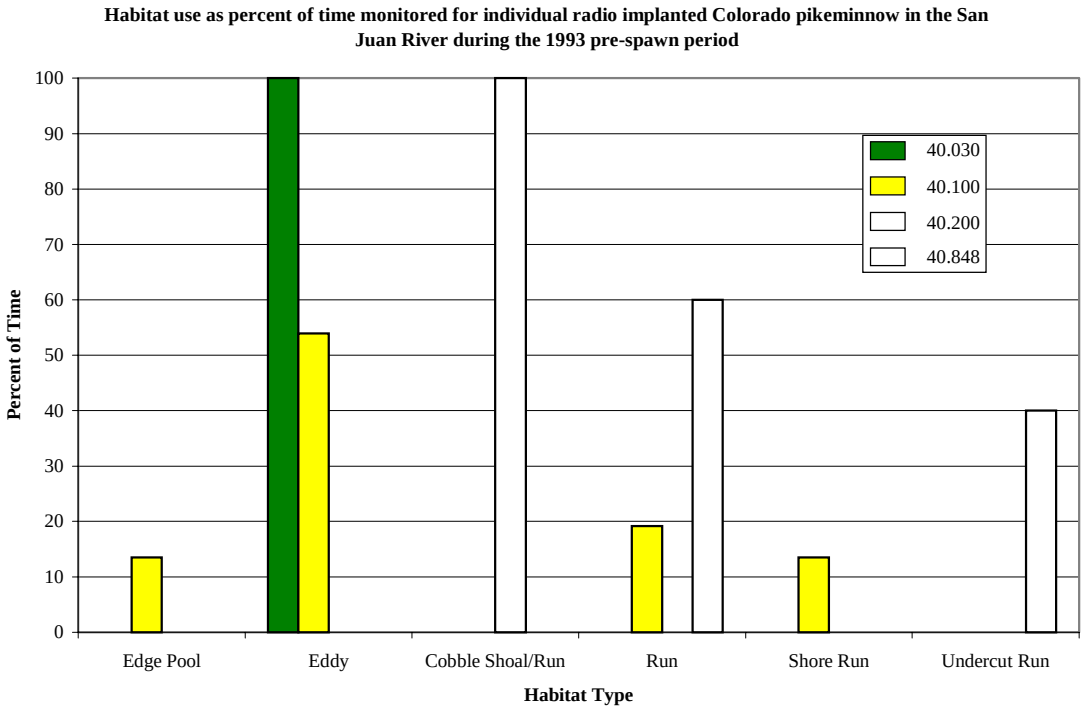
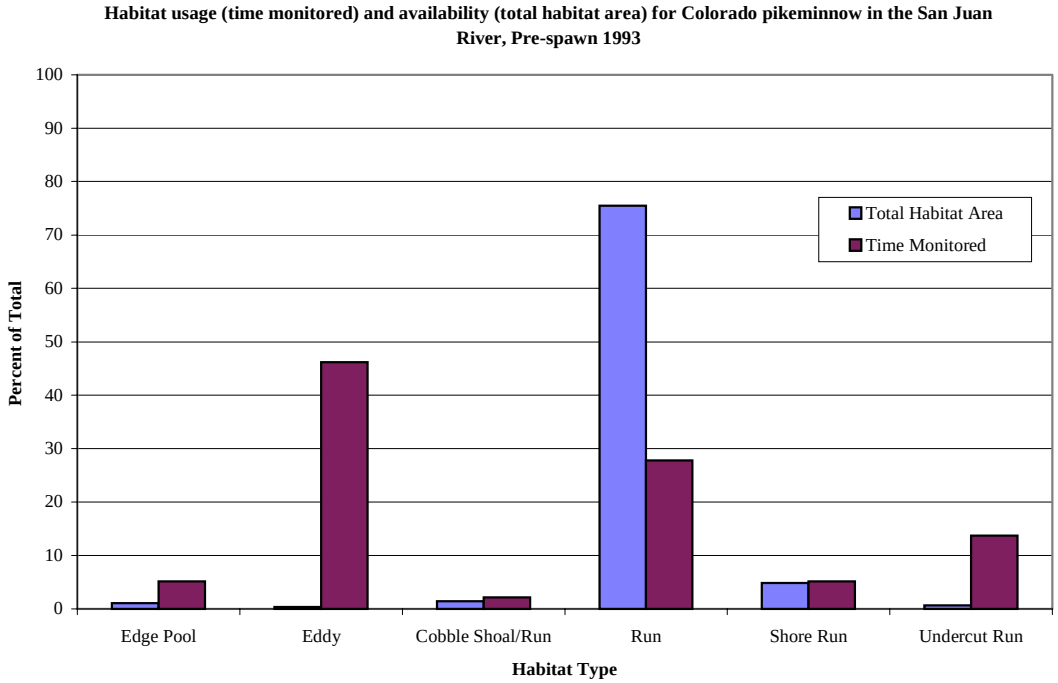


Figure 5. Habitat usage and habitat availability as a percent of total during the pre-spawn period, 1993.

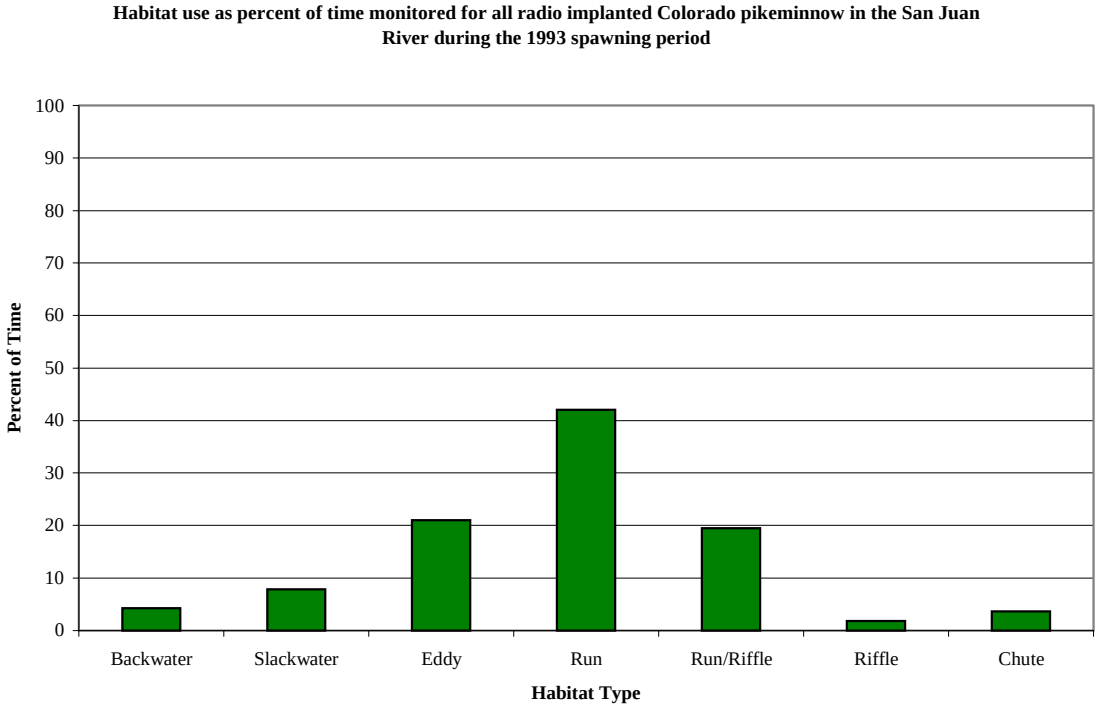


Spawning

During the 1993 spawning period, radio implanted fish spent over 40% of the time in run habitat and approximately 20% of the time in eddy and run/riffle habitats (Figure 6). Backwater, slackwater, riffle and chute habitats were also utilized, but none accounted for more than 8% of the time monitored (Figure 6). All radio implanted pikeminnow except 40.100, which could not be located after 12 July 1993, used higher velocity habitats (run/riffle, riffle and chute) during the spawning period (Figure 6). Fish 40.100 spent the majority (58%) of its time in backwater habitat. Slackwater, eddy and run/riffle habitats had the highest selectivity (Figure 7). Selectivity was also shown for backwater and chute habitats, but to a lesser extent than slackwater, eddy and run/riffle habitats (Figure 7).

Based upon fish aggregations and visual observations, two locations were identified as potential spawning areas. Both of the locations are within the "Mixer" reach of the river. The upper spawning location was at RM 132.0 and the lower spawning location was at RM 131.1. Both locations are characterized by cobble bar and island complexes. Radio implanted fish displayed directional movement to these potential spawning sites. Between 1 July 1993 and 12 July 1993, fish 40.100 moved 8.6 miles upstream and fish 40.848 moved 5.3 miles downstream to reach the RM 132.0 site. Fish 40.030 moved 8.6 miles upstream to reach the RM 131.1 site.

Figure 6. Habitat use as a percent of time monitored during the spawning period, 1993.



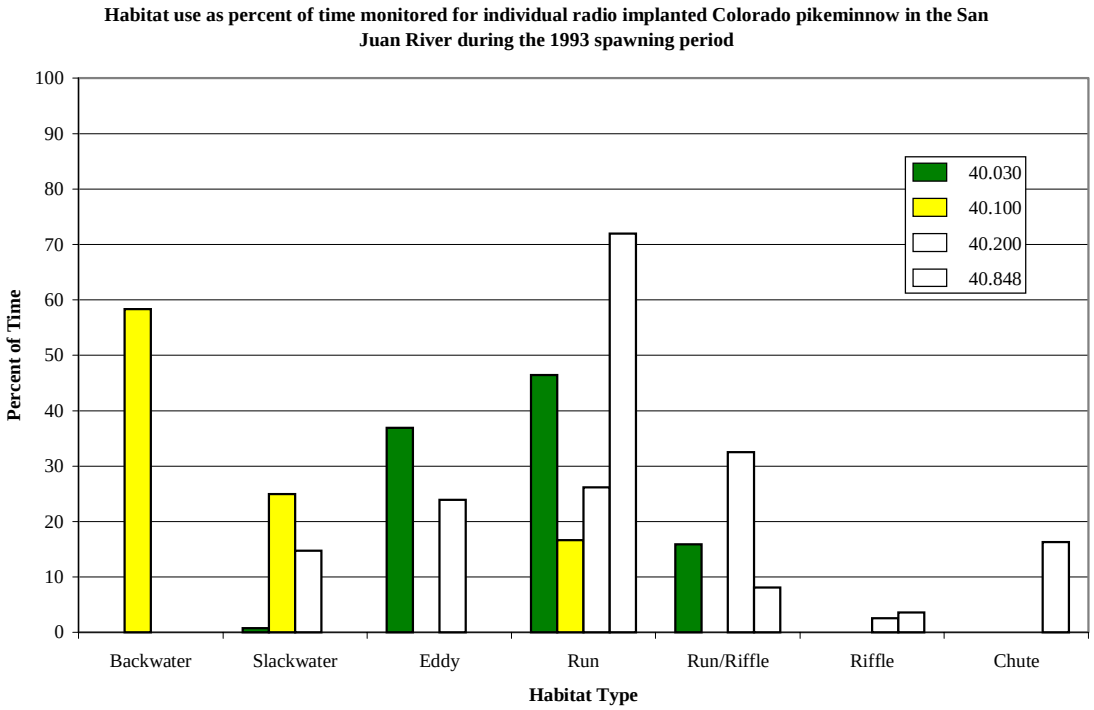
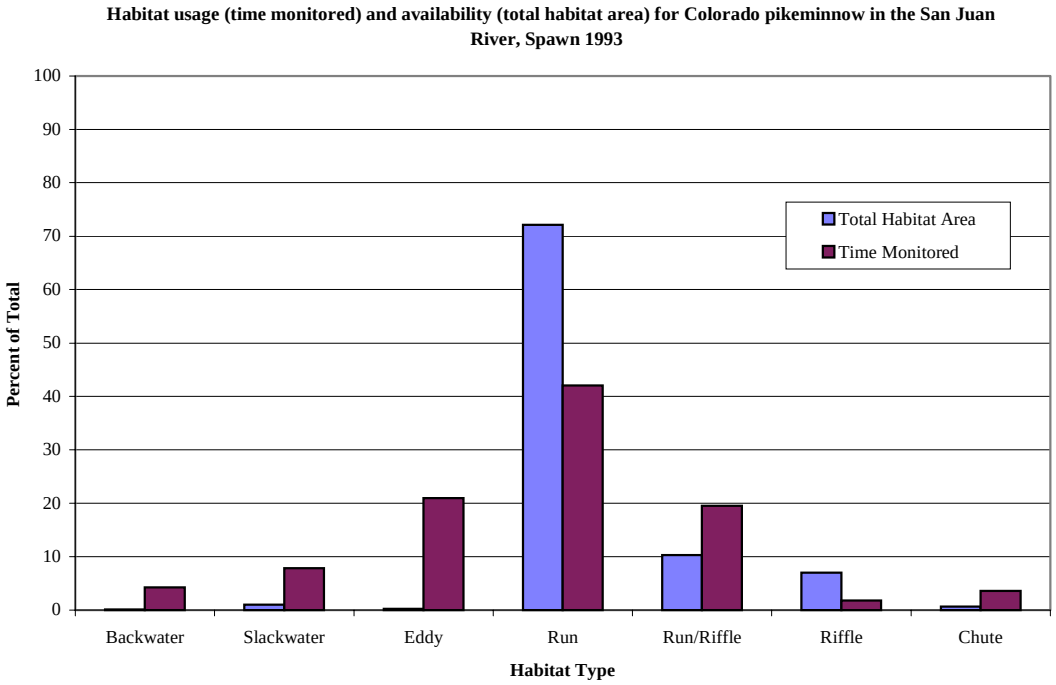


Figure 7. Habitat usage and habitat availability as a percent of total during the spawning period, 1993.



River Mile 132.0

Three implanted fish moved to the potential spawning location at RM 132.0 prior to 12 July 1993. On 12 July, fish 40.100 and 40.848 were located and monitored near the side channel on river left, while fish 40.200 was located in a main channel riffle. RM 132.0 had 12 different habitat types present during the 12 – 16 July 1993 period. This area is similar to spawning habitats found in the Yampa River, Colorado; a side channel branches to form several fast, deep chute, run/riffle or riffle habitats. Resting habitats were adjacent to the chutes where a large slackwater (main channel edge) and a smaller backwater were located. The chutes and riffles emptied into a uniformly deep, slow run habitat approximately 60-75 m downstream from the entrance of the side channel. This long, slow run may provide a feeding/resting area for spawning fish. Cobble in the riffle areas was unsettled and clean in the higher velocity areas, while on the slower riffle edges the cobble was covered with a thin growth of algae. Water temperatures on 12 July 1993 were 25^{o}C in all local habitat types.

The RM 132.0 site was occupied until 16 July 1993 and then abandoned by all radio implanted fish. Contact with fish 40.100 was lost after 12 July 1993 and not regained for the remainder of monitoring. Fish 40.030, 40.200, and 40.848 moved to the suspected downstream spawning area at RM 131.1.

River Mile 131.1—Red Wash Side Channel

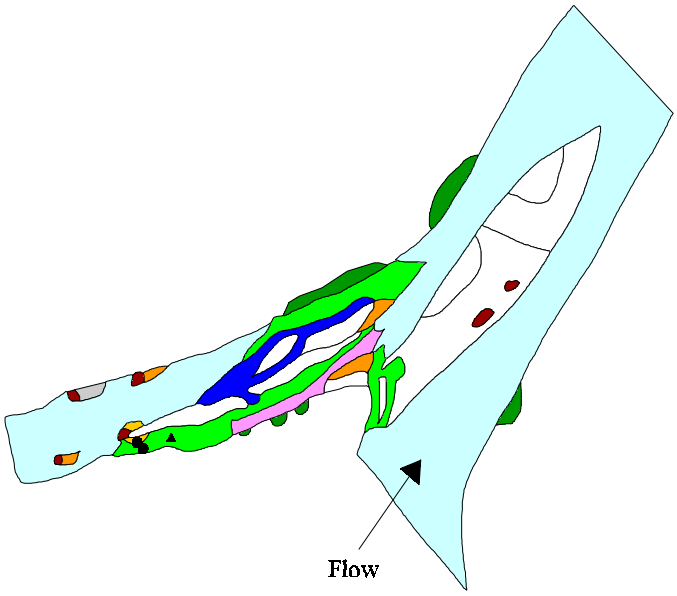
The suspected spawning area at RM 131.1 is located at the mouth of the side channel containing the Red Wash confluence. This location was a side channel in 1992, but has carried main channel flow since high runoff in the spring of 1993 eroded a narrow bank separating the primary and secondary channels. This area was similar in physical features to RM 132.0; there was an island complex with a side channel and chute, and the dominant substrate was cobble. Seven different aquatic habitat types were present on 20 July 1993 (Figure 8). The discharge on this date at the Four-Corners gage was 1110 cfs. The first use of this location by radio implanted fish (40.848) was documented on 13 July 1993.

Habitat in the suspected spawning location included a fast, narrow chute with an adjacent small eddy, which may act as resting habitat. Depth and velocity measurements in the eddy were 0.85 m and 0.29 m/s, respectively (Table 8). Cobble diameter was 8-10 cm in the chute. Russian olive trees overhang the chute providing shade and cover.

Table 8. Microhabitat measurements for possible spawning activities.

Habitat	Habitat Function	Depth (m)	Mean Velocity (ms)	Year
Eddy	Resting	0.85	0.29	1993
Eddy	Resting	0.91	0.02	1994
Run/Riffle	Spawning	0.46	1.25	1994
Eddy (pt 1)	Resting	0.70		1998
Eddy (pt 2)	Resting	0.98		1998
Riffle (pt 3)	Spawning	0.55		1998
Riffle (pt 4)	Spawning	0.46		1998

Figure 8. Suspected spawning location 1993.



Map not to scale

River Mile 131.1, 20 July 1993

Slackwater	Run/Riffle	Rootwad
Eddy	Riffle	Land Feature
Sand Shoal	Eddy/Riffle	Frequency 40.030, 40.200
Run	Overhanging Veg	Frequency 40.030

Visual Sighting of Spawning Colorado Pikeminnow.

On 20 July 1993, at 0825 hrs fish 40.200 and 40.030 (male and female, respectively) were located together at RM 131.15. Both fish were approximately 12-18 m downstream of the side channel entrance. A large debris pile at the front of an island formed a large (5 m x 6 m), deep (>1.0 m) eddy and a deep run/riffle. Although the cobble (8-10 cm diameter) had a thin growth of algae on the surface, the interstitial spaces were clean and extended 16-20 cm deep.

At 0940 hrs both fish were located near the top of a shaded run/riffle in the deepest, fastest area. When not together, the male would maintain a 2 - 4 m downstream separation with the female. Occasionally, the male (40.200) would move up to the female and then move downstream 7 - 10 m. In contrast to the male's active movement, the female's movement appeared to be slow and deliberate. When the shade left the lower run/riffle, the fish moved up into deeper water at the top end of the run/riffle.

At 1025 hrs the fish were visually observed and confirmed by radio telemetry in a side by side pairing. The fish moved upstream of the fast current (run/riffle) and into the bottom end of the eddy. The larger female fish was positioned in front of the male who was on her right side, snout even with her vent. The fish were within 14 cm of each other. The observation lasted approximately 3-5 seconds before both fish moved into the deeper part of the eddy. The fish spent approximately 10 to 15 minutes in the deep swift water before they moved into the eddy. At 1035 hrs two smaller, paired fish were observed moving slowly through the eddy. One fish had a fungal growth on its dorsal side. The two fish were dark gray in appearance and smaller than the radio implanted fish. Neither of the radio implanted fish had any observed fungal growth. On two different occasions, a very large, reddish brown caudal fin was observed coming out of the water at the upper edge of the eddy. On the river right bank, a caudal fin approximately 7.5 cm in height, lobed, and orange tinted was observed breaking the surface, but the body was not visible.

Post-spawn

During the post-spawn period radio implanted fish locations ranged from RM 129.8 upstream to RM 142.0. Fish 40.848 moved upstream to RM 142.0 and remained in that area until the end of monitoring , while fish 40.030 and 40.200 remained within the RM 131.0 to RM 132.0 area. These fish showed little directional movement during this period, moving only an average of 0.72 miles.

Radio implanted fish spent over 80% of the time in runs and 15% of the time in chute habitat (Figure 9). Fish 40.848 and 40.030 spent the majority of time in runs while fish 40.200 used chute habitat exclusively (Figure 9). Chute habitat was the only habitat selected for during the post-spawn period (Figure 10).

Figure 9. Habitat use as a percent of time monitored during the post-spawn period 1993.

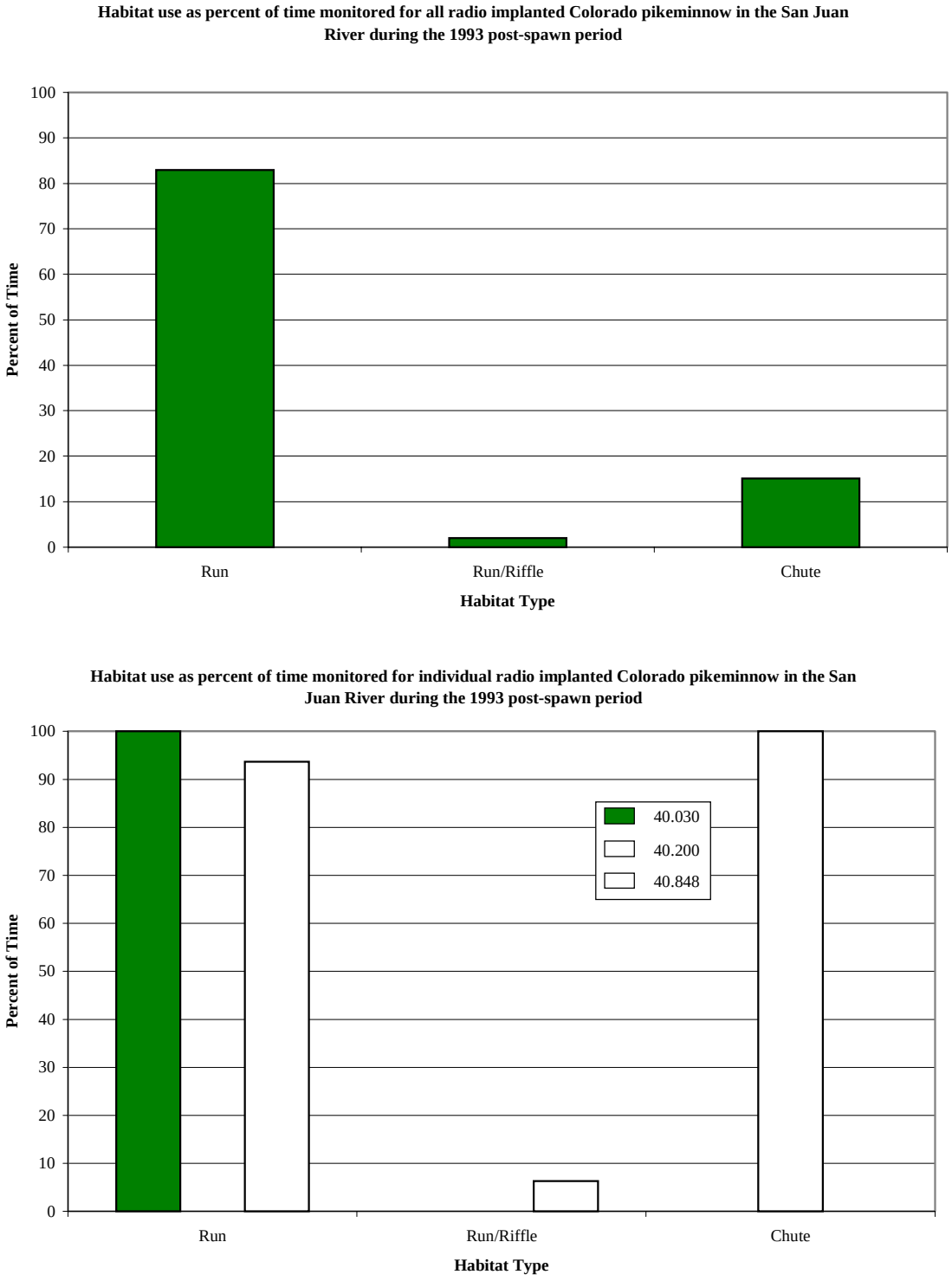
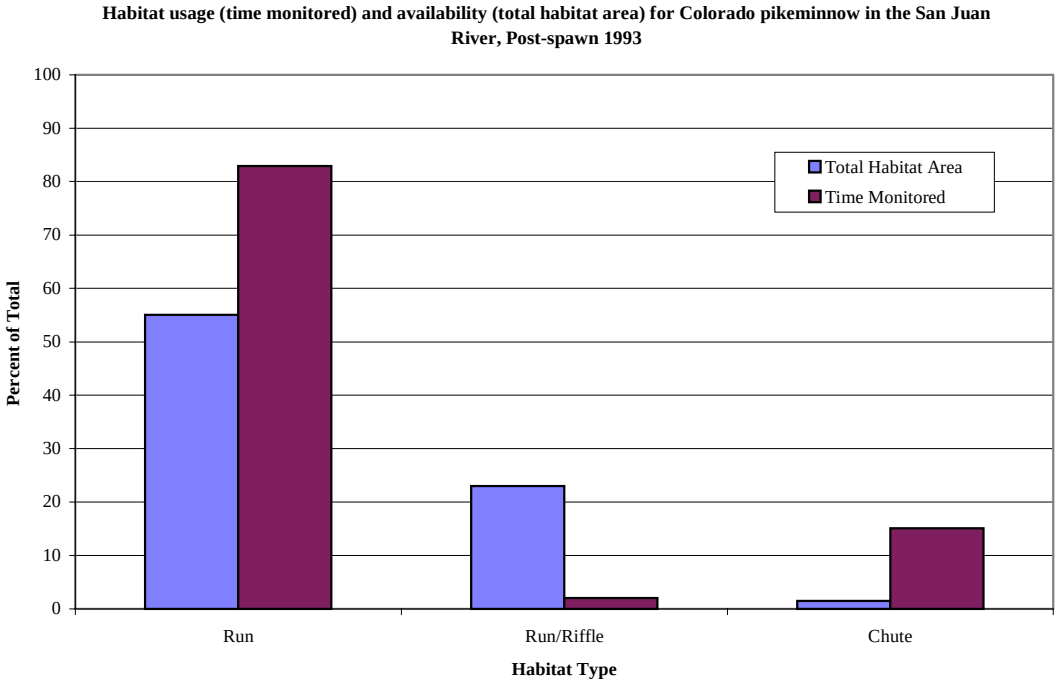


Figure 10. Habitat usage and habitat availability as a percent of total during the post-spawn period, 1993.



1994

Radio implanted Colorado pikeminnow were opportunistically tracked in conjunction with other San Juan River studies during February, May, June, October and November, 1994. Intensive radio tracking of Colorado pikeminnow was conducted during the period from 27 May – 29 July 1994. Three new pikeminnow were captured in 1994 and implanted with radio transmitters. Additionally, two pikeminnow monitored during 1993 were monitored again in 1994 bringing the total number of fish monitored to five (Table 1).

Radio implanted fish used predominately run habitat followed by slackwater, run/riffle and eddy habitat (Figure 11). Cobble shoal/run, riffle, riffle/chute and chute habitat were also used but none accounted for more than 3% of the total time monitored (Figure 11). Individually, all five fish monitored spent more than 50% of their time in run habitat (Figure 11). Monitored fish used a total of eight different habitat types, but only run and slackwater habitat was used by all fish. Cumulative data indicates a high degree of selectivity for slackwater and eddy habitats (Figure 12).

Habitat richness was highest during the fall and winter monitoring periods (Table 6). During the summer, the spawning period had more habitat richness than the pre-spawn and post-spawn periods (Table 6).

Figure 11. Habitat use as percent of time monitored during the summer 1994.

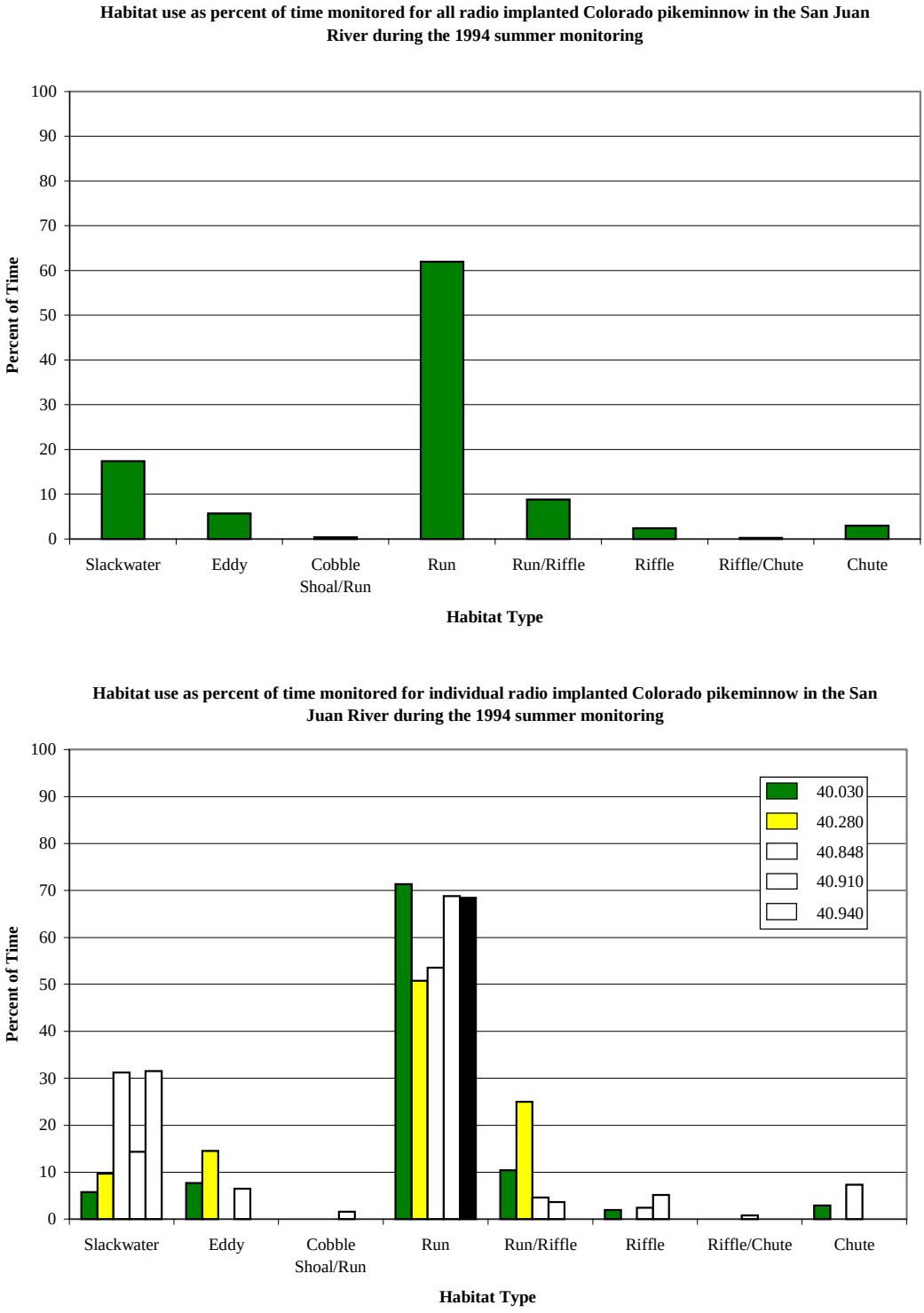
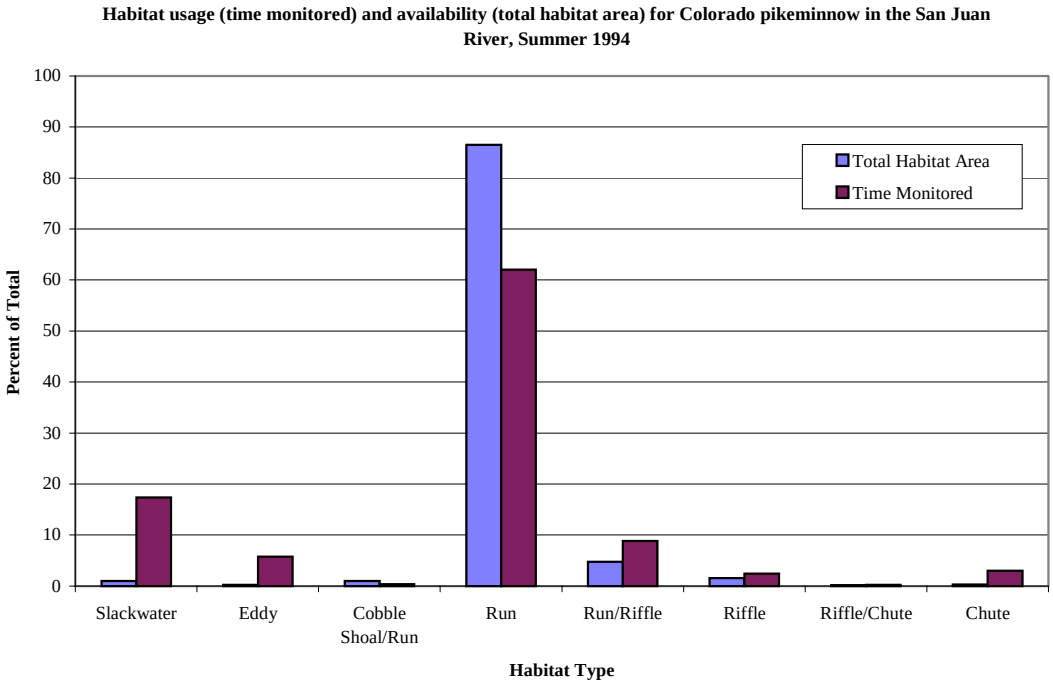


Figure 12. Habitat usage and habitat availability as a percent of total during the summer 1994.



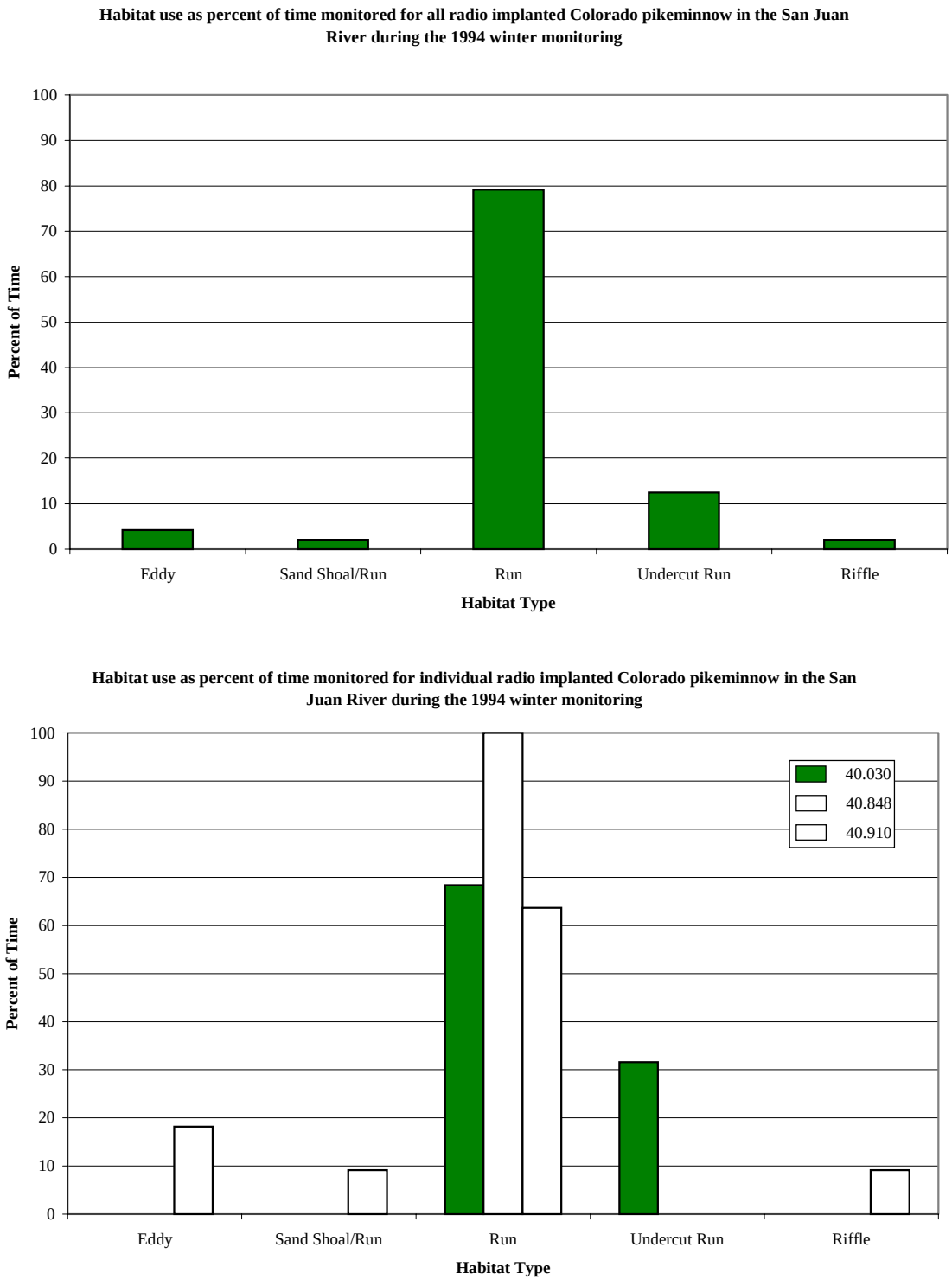
Winter

One week of monitoring was conducted in February, 1994. Three fish, radio tag numbers 40.030, 40.910 and 40.848, were tracked from 17 February – 21 February 1994. Fish 40.030 and 40.910 moved 0.50 mi during this period and fish 40.848 moved 0.10 mi (Table 9). Radio implanted fish used run habitat almost exclusively, although, eddy, sand shoal/run, undercut run and riffle habitats were also utilized (Figure 13). All individual fish used run habitat over 60% of the time (Figure 13). Fish 40.848 showed the most diversity in habitat use, using run, eddy, sand shoal/run and riffle habitats (Figure 13). All fish monitored were active during observation periods and the highest level of activity occurred during mid-day.

Table 9. River mile locations for monitored Colorado pikeminnow, Winter and Fall 1994.

	Fish Frequency				
Date	**40.030**		**40.848**	**40.910**	
2/17/94	128.20		131.90		
2/18/94				75.10	
2/19/94	127.90		131.80		
2/20/94	127.70			74.60	
2/21/94	127.70		131.80		
Movement					
MIN (RM)	127.70		131.80	74.60	
MAX (RM)	128.20		131.90	75.10	
GROSS (mi)	0.50		0.10	0.50	
	Fish Frequency				
Date	**40.030**	**40.280**	**40.848**	**40.910**	**40.940**
10/3/94		133.50	135.70		
10/4/94	128.70	133.50			120.90
10/5/94				74.30	
11/14/94			136.30		
11/15/94				74.85	119.80
11/16/94			136.30	74.85	119.80
Movement					
MIN (RM)		133.50	135.70	74.30	119.80
MAX (RM)		133.50	136.30	74.85	120.90
GROSS (mi)		0.00	0.60	0.55	1.10

Figure 13. Habitat use as percent of time monitored during the winter 1994.



Pre-spawn

Radio implanted Colorado pikeminnow were widely distributed during this period, with locations ranging from RM 73.8 to RM 137.5 (Table 10). However, three fish (40.030, 40.280, and 40.940) were located at the same river mile (122.6), although each was found in distinctly different sections of the river. These three fish moved only short distances during this period, exhibiting gross movements of only 2.50, 0.10, and 0.0 mi, respectively. Two fish (40.940 and 40.030) were found using the Mancos River, which had water temperatures two to four degrees warmer than the San Juan River main channel (Table 7).

Two fish showed directional movement during this period. Fish 40.848 left RM 137.5, where she had been located since 27 May 1994, on 20 June 1994 and moved 9.17 kilometers downstream by 30 June 1994. Fish 40.910 moved the longest distance of any monitored fish in 1994. On 1 June 1994, fish 40.910 was located at RM 73.8 and by 30 June 1994 this fish had moved upstream to RM 131.2—a distance of 57.40 mi and a rate of almost than 2.0 mi per day (Table 10).

Radio implanted fish used only three habitat types during this period (Figure 14). The fish predominately used run habitat, but they were also found in slackwater and eddy habitats (Figure 14). Fish 40.910 spent 80% of its time in runs, while fish 40.280 used runs exclusively (Figure 14). Fish 40.848 and 40.030 spent over half of their time in the low velocity slackwater and eddy habitats (Figure 14). Cumulative data indicates a selectivity toward slackwater and eddy habitats during the pre-spawn period (Figure 15).

Table 10. River mile locations for Colorado pikeminnow, May – July 1994.

	Fish Frequency				
Date	**40.030**	**40.280**	**40.848**	**40.910**	**40.940**
5/27/94			137.50		
6/1/94				73.80	
6/3/94					122.60
6/6/94			137.50		122.60
6/7/94	122.60	122.60	137.50		122.60
6/10/94	122.60		137.50		122.60
6/14/94				87.20	
6/17/94		122.70			122.60
6/20/94	122.75	122.70	137.50		
6/21/94	120.00	122.70		96.10	
6/27/94			133.00		
6/28/94	120.7			126.50	
6/29/94				128.20	
6/30/94	124.40 (1330)	122.60	131.80	131.20	
6/30/94	122.20 (1700)				
7/1/94				135.40	
7/2/94			132.00	134.50	
7/3/94			132.00	133.20	
7/4/94			132.00	133.20	
7/5/94	132.00		132.00	131.80	
7/6/94	132.00		132.00 (0845)		
7/6/94			131.90 (1345)		
7/6/94			132.00 (2145)		
7/7/94	132.10 (1700)	122.60	132.00	131.40 (0915)	
7/7/94	132.00 (1830)			131.50 (1915)	
7/8/94	132.00	122.60	132.00	131.60	
7/11/94		122.60	131.20	131.60 (1245)	
7/11/94				131.20 (1540)	
7/12/94	131.20		131.20 (1155)	131.20	134.40
7/12/94			132.00 (1925)		
7/13/94				131.20	134.50
7/14/94	129.20	122.00			
7/15/94			135.40	133.50	135.40
7/18/94		122.30		133.40	
7/19/94			135.40	133.20	
7/20/94	124.20	122.05	135.80	133.30	
7/21/94		122.05	135.80	133.40	
7/22/94				133.30	
7/25/94			131.40	133.50	
7/26/94	129.70 (0750)	122.05	131.20	134.20	
7/26/94	129.90 (1945)				
7/27/94	129.80		131.10	134.10	142.05
7/28/94	129.80	122.05			142.05
7/29/94	130.50		131.05	133.50	
Movement	**40.030**	**40.280**	**40.848**	**40.910**	**40.940**
MIN (RM)	120.70	122.05	131.05	73.80	122.50
MAX (RM)	132.10	122.70	137.50	135.40	142.05
GROSS (mi)	11.40	1.65	6.45	61.60	19.55

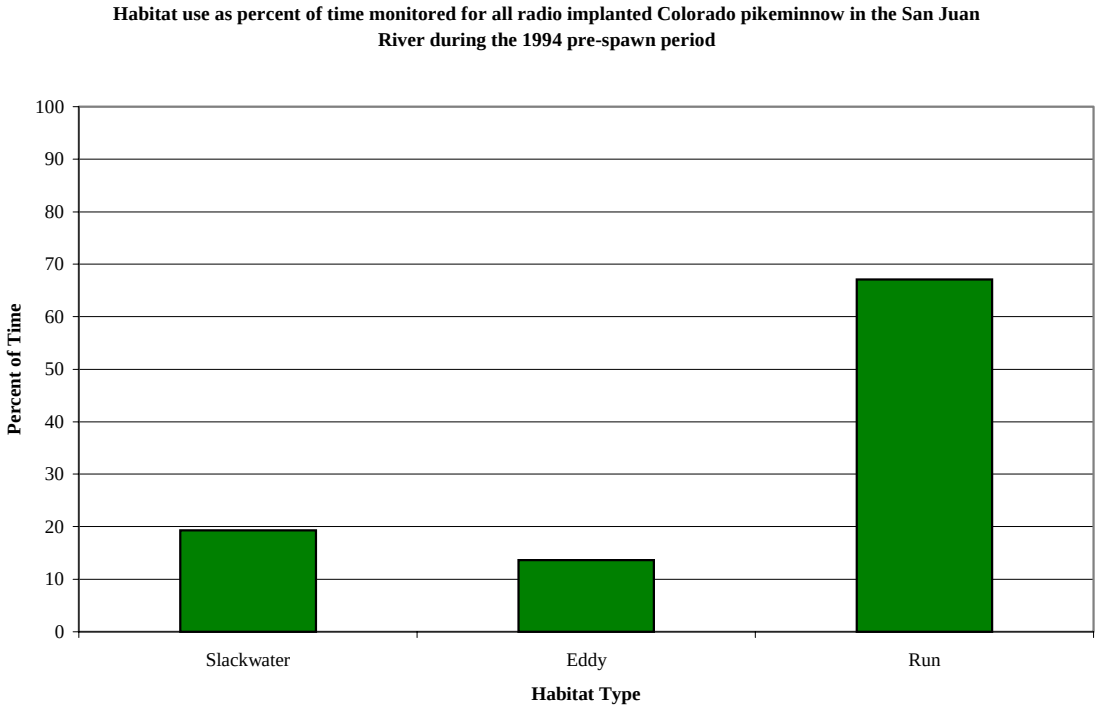
Table 11. Distance (m) moved upstream or downstream by Colorado pikeminnow during daily monitoring in the San Juan River, July 1994.

	Fish Frequency				
Date	40.030	40.280	40.848	40.910	40.940
7/5/94	36		9	5	
7/6/94	175		294		
7/7/94	91		12		
7/8/94			125		
7/11/94			18	3	155
7/12/94	169			107	
7/13/94				6	
7/14/94		70			
7/15/94			21	6	9
7/18/94					
7/19/94			6		
7/20/94	122	6			
7/21/94					
7/22/94				24	
7/25/94			134		
7/26/94	113	3		500	
7/27/94	12		21		256
7/28/94	6	207			24
7/29/94			6		

Table 12. Distance (mi) moved between the first and last daily contact of monitored Colorado pikeminnow, July 1994.

	Fish Frequency				
Date	**40.030**	**40.280**	**40.848**	**40.910**	**40.940**
7/5/94	0		0	0	
7/6/94	0		0.10		
7/7/94	0.10	0	0	0.10	
7/8/94	0	0	0	0	
7/11/94		0	0	0.40	0.10
7/12/94	0			0.80	
7/13/94				0	0
7/14/94	0	0			
7/15/94			0	0	0
7/18/94		0		0	
7/19/94			0	0	
7/20/94	0	0	0	0	
7/21/94		0	0	0	
7/22/94				0	
7/25/94			0.20	0	
7/26/94	0.20	0	0	0.10	
7/27/94	0		0	0	0
7/28/94	0	0			0
7/29/94	0		0	0	

Figure 14. Habitat use as a percent of time monitored during the pre-spawn period 1994.



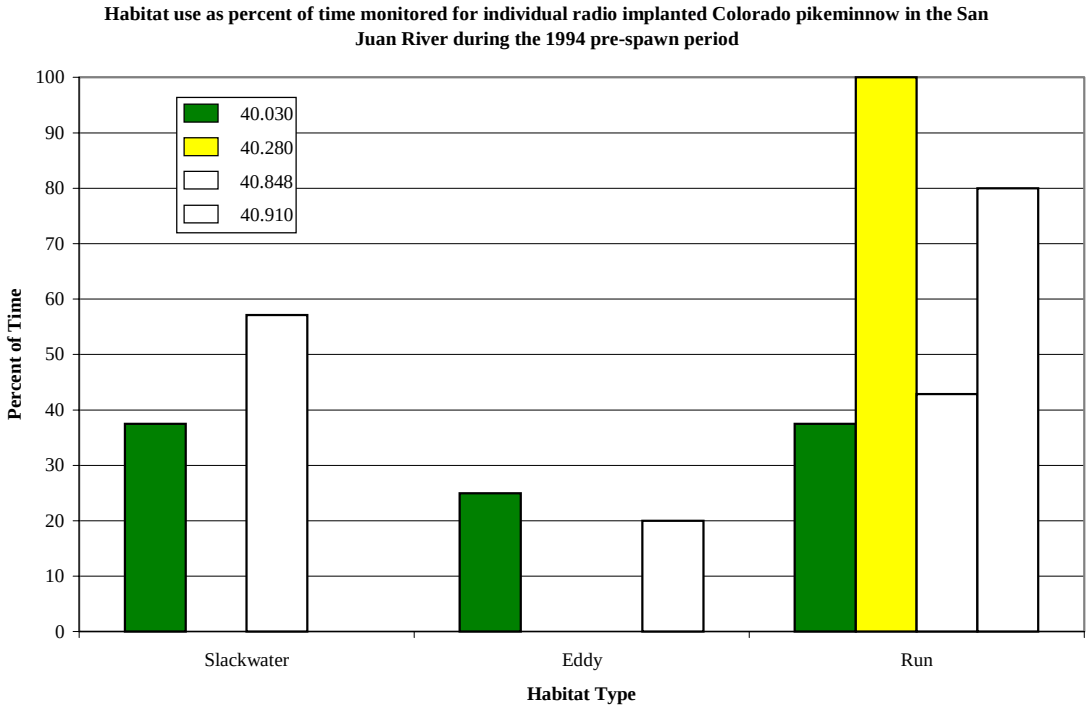
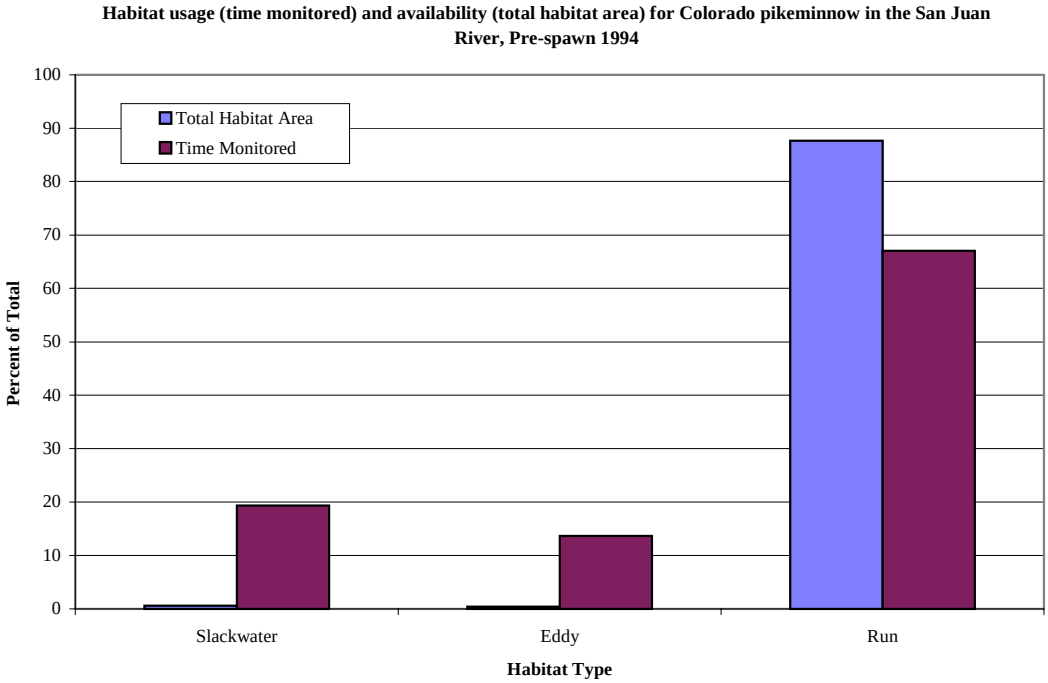


Figure 15. Habitat usage and habitat availability as a percent of total during the pre-spawn period, 1994.



Spawning

The potential spawning locations used during the 1993 monitoring were once again used in 1994 by radio implanted Colorado pikeminnow, however, different sections of the river channel at RM 131.1 were used in 1994 than in 1993. Fish 40.030, 40.848, and 40.910 were all located during the spawning period at the potential spawning sites at either RM 131.1, RM 132.0 or both. Fish 40.280 stayed near RM 122.0 for the entire period. Fish 40.940, who had not been contacted since 17 June 1994, was located on 12 July 1994 at RM 134.4 and subsequently moved upstream to RM 142.05 by 27 July 1994 (Table 10).

Colorado pikeminnow exhibited daily movements of several to several hundred meters during the spawning period (Table 11). Pikeminnow did not show long distance movement during this July period but were rather sedentary at particular river miles for each date (Table 12). The largest daily movement was 0.80 mi by Colorado pikeminnow 40.910. Most fish remained at the same river mile between the first and last daily contact.

Run habitat was the most used habitat during the 1994 spawning period, accounting for over 60% of the total time monitored (Figure 16). The second most used habitat was slackwater, which was used 17.2% of the time. Overall, radio implanted fish were found in eight different habitats during this period (Figure 16). Fish 40.848 had the highest

diversity in habitat use, using six of the eight habitat types. All fish, except for 40.280, spent more than 50% of their total time using run habitat. Fish showed definite selectivity for slackwater habitat and to a lesser extent for eddy, run/riffle, riffle and chute habitat (Figure 17).

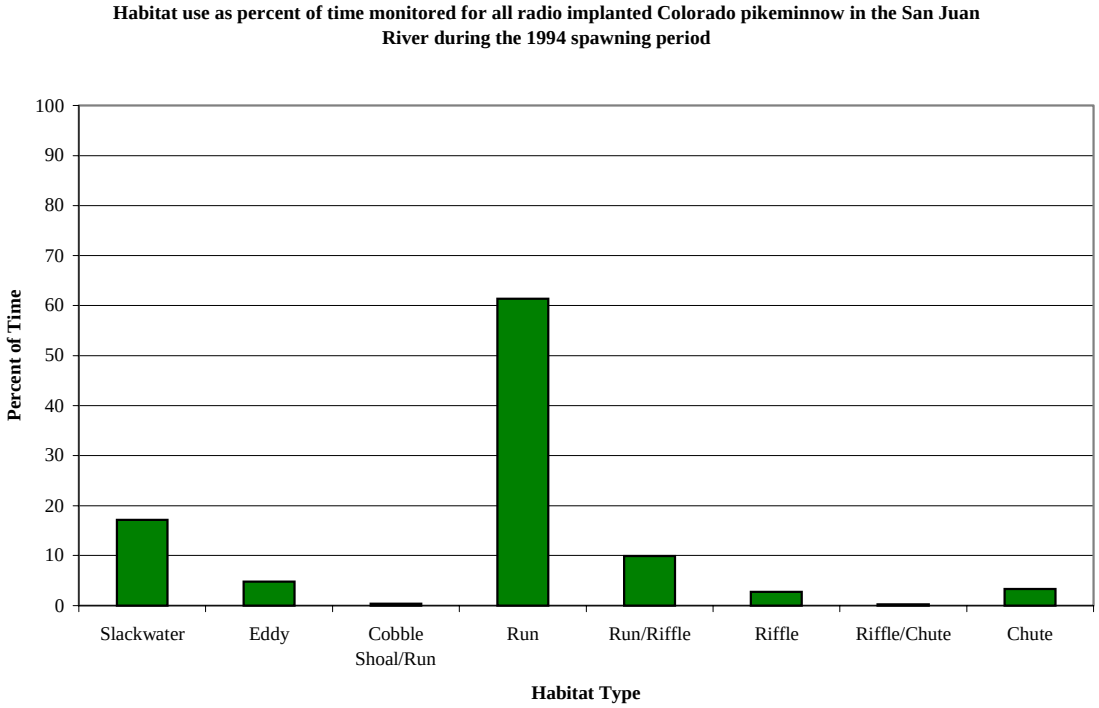
River Mile 132.0

Fish moved to this location the first week in July, 1994. On 5 July 1994, fish 40.030 and 40.848 were located and monitored near the entrance to the river left side channel. The potential spawning site at RM 132.0 was used by radio implanted fish from 2 July – 8 July 1994. Individual fish were never monitored in the same location and at the same time as another implanted fish, although each fish did use the same location at different times. The area used during 1994 is similar to the suspected spawning habitats used at this location in 1993; a side channel branches off then splits at the top to form several fast, deep chute, run/riffle or riffle habitats. Resting habitats are adjacent to these chutes where a large slackwater (main channel edge) and a smaller backwater are available. Water temperatures on 11 July were 20^{o}C in all local habitat types. The RM 132.0 area was occupied through 12 July 1994 and then abandoned.

River Mile 131.1—Red Wash Side Channel

This suspected spawning area is located in the main channel upstream of the mouth of Red Wash. This location was used in 1993 and in 1994 it was occupied by radio implanted fish from 11 July - 13 July 1994 (Figure 18). Use of this potential spawning site changed from 1993 to 1994. In 1993, the radio implanted fish had used the river left channel , but in 1994 the fish used an area in the river right channel (Figure 18). Microhabitat depth and velocity measurements were 0.91 m and 0.02 m/s for the resting habitat (eddy) and 0.46 m and 1.25 m/s for the spawning habitat, respectively. On 12 July 1994, three fish, 40.030, 40.848 and 40.910 were present at the same time at this suspected location. At the Four Corners gage the discharge was 2190 cfs on this date. The last fish (40.910) left the site on 13 July 1994.

Figure 16. Habitat use as percent of time monitored during the spawning period 1994.



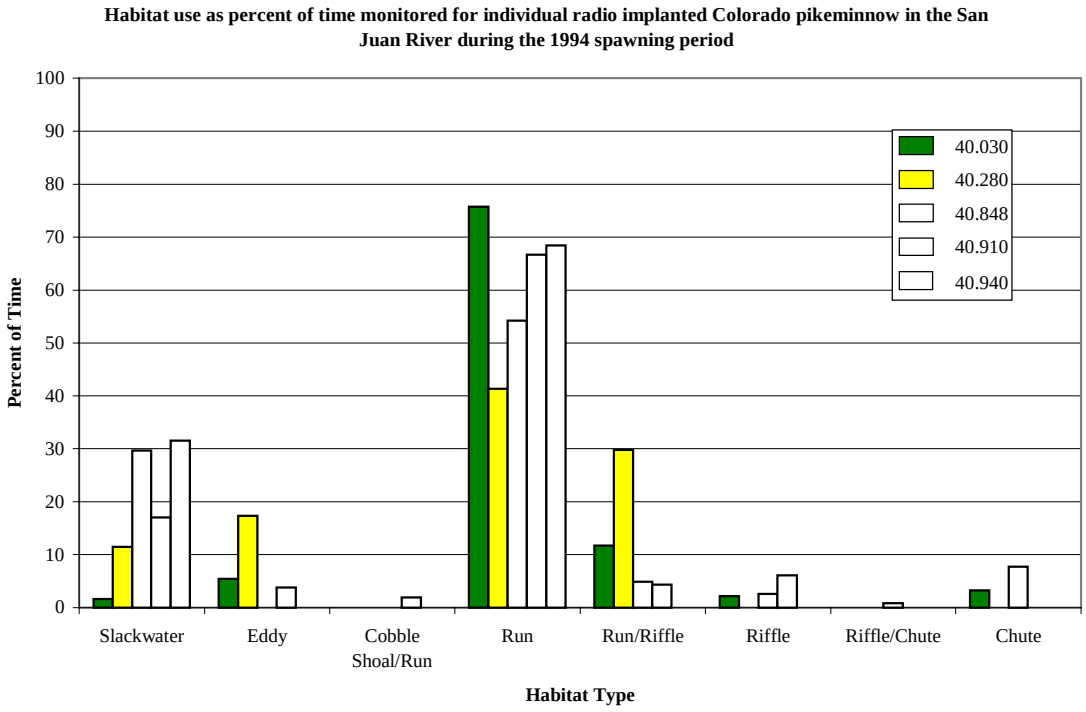
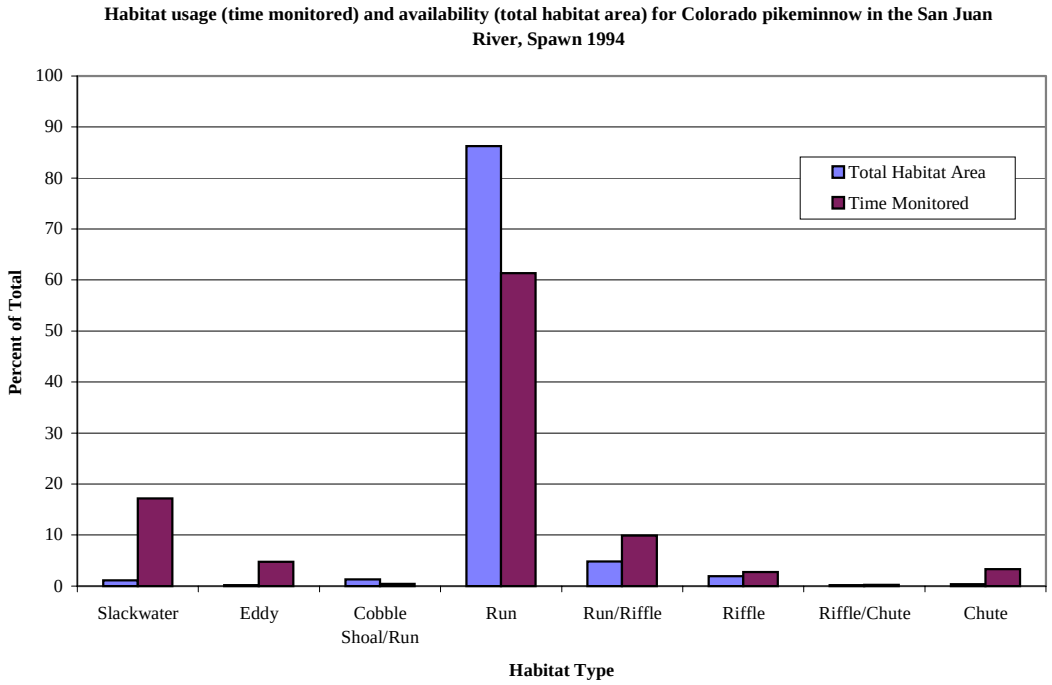


Figure 17. Habitat usage and habitat availability as a percent of total during the spawning period, 1994.

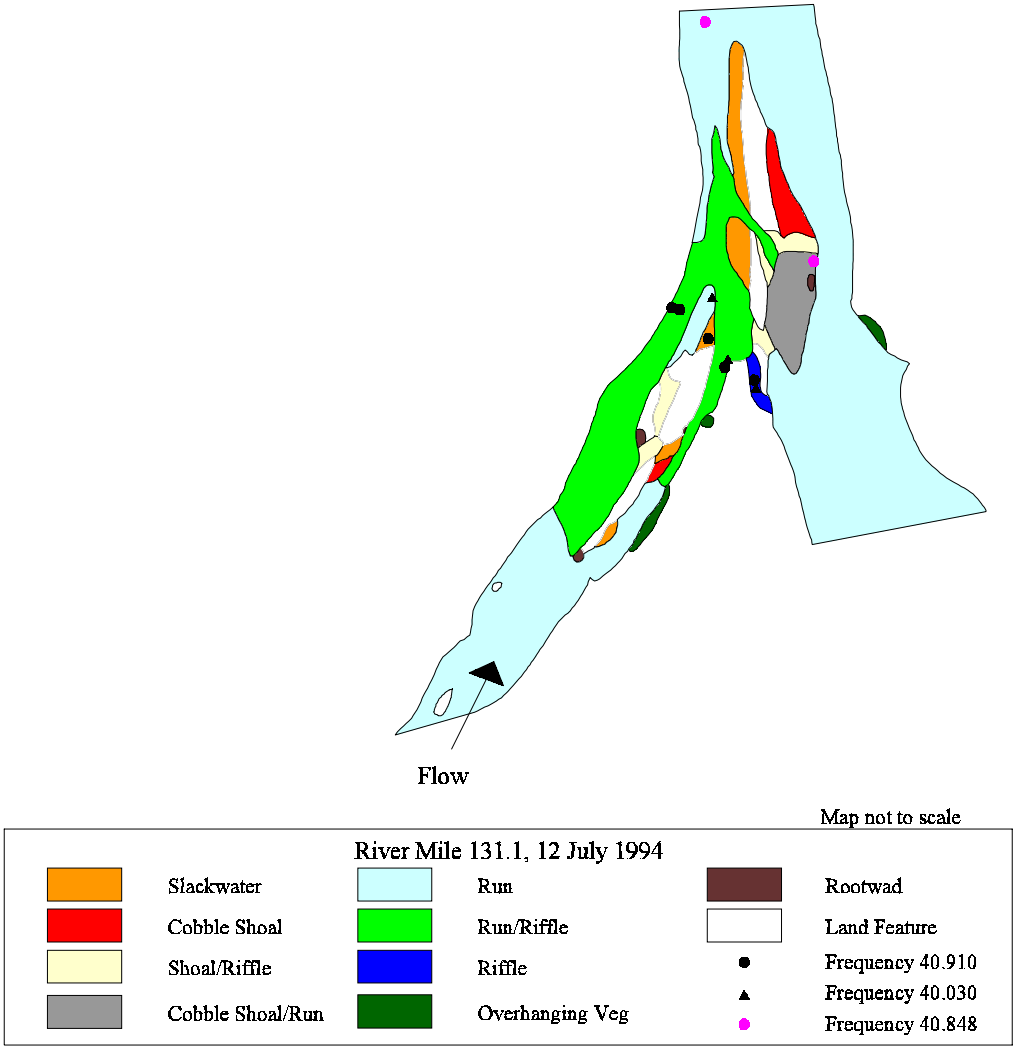


Fall

All fish remained separated during fall observations in October and November. Three fish, 40.030, 40.910 and 40.940, moved downstream from their last spawning period locations, while two fish, 40.280 and 40.848, moved upstream from their last contact. From 29 July to 5 October 1994, fish 40.910 moved almost 60 miles downstream to within 0.5 miles of his 1 June 1994 contact (Table 9).

Cumulatively, the most used habitat type during the fall monitoring was run habitat. All fish used just one type of habitat during the monitoring. Fish 40.848, 40.910, and 40.940 used run habitat, while fish 40.280 used a pool and fish 40.030 used eddy habitat.

Figure 18. Suspected spawning location 1994.



1993 and 1994 Combined

A total of seven Colorado pikeminnow were monitored during 1993 and 1994 (Table 1). Five were monitored for only one year (two in 1993, three in 1994), while two fish (40.030 and 40.848) were monitored both years. The majority of fish contacts occurred in the area from RM 120 to RM 142. Fish 40.910 had the farthest downstream contact at RM 73.8, while fish 40.940 had the highest upstream contact at RM 142.05. Fish 40.910 exhibited the longest migratory movement of all monitored fish. This fish moved from RM 73.8 in early June 1993 up to RM 135.4 by July 1993 and back down to RM 74.3 in October 1993. The six remaining fish had an average gross movement of 8.70 miles.

Radio implanted fish spent the majority of the time monitored in run habitat followed by eddy, slackwater, and run/riffle (Figure 19). Together, those four habitats accounted for over 88% of the total time monitored, although, a total of 12 different habitat types were used. Only fish 40.100 and 40.200 spent less than 50% of their time in run habitat, the remaining five fish spent the majority of their time in runs (Figure 19). Slackwater was the only other habitat used by all fish (Figure 19). Eddy, slackwater and run/riffle were the most selected for habitats (Figure 20).

Pre-spawn

During the 1993 and 1994 pre-spawn period most fish did not display directional movement. Four fish moved less than 0.5 mi during the period. Fish 40.030 and 40.848, the only fish monitored both years, showed the same movement trend. In 1993, fish 40.030 and 40.848 moved 0.0 and 0.4 mi, respectively, however, in 1994 fish 40.030 moved 4.40 mi and fish 40.848 moved 5.70 mi.

Radio implanted fish used eddy and run habitat the majority of the time, accounting for 37.3% and 38.5% of the total time, respectively (Figure 21). No other habitat type accounted for more than 10% of the time monitored. Individually, fish 40.030 and 40.100 spent the majority of their time in eddy habitat; fish 40.200 in cobble shoal/run, and fish 40.280, 40.848 and 40.910 in run habitat (Figure 21). Fish showed a high amount of selectivity for eddy habitat during this period (Figure 22).

Figure 19. Habitat use as a percent of time monitored during the summers 1993 and 1994 combined.

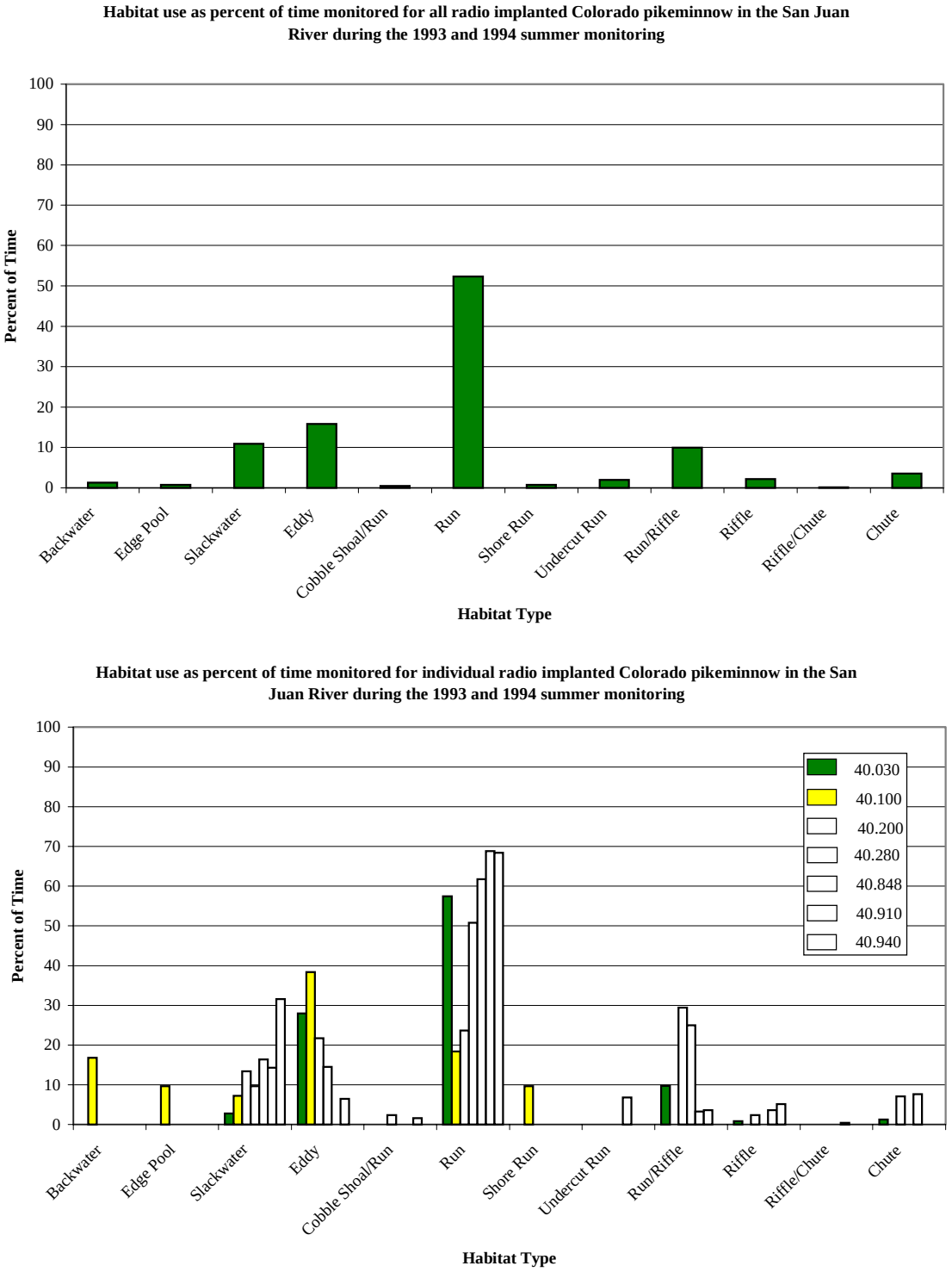


Figure 20. Habitat usage and habitat availability as a percent of total during the summers of 1993 and 1994.

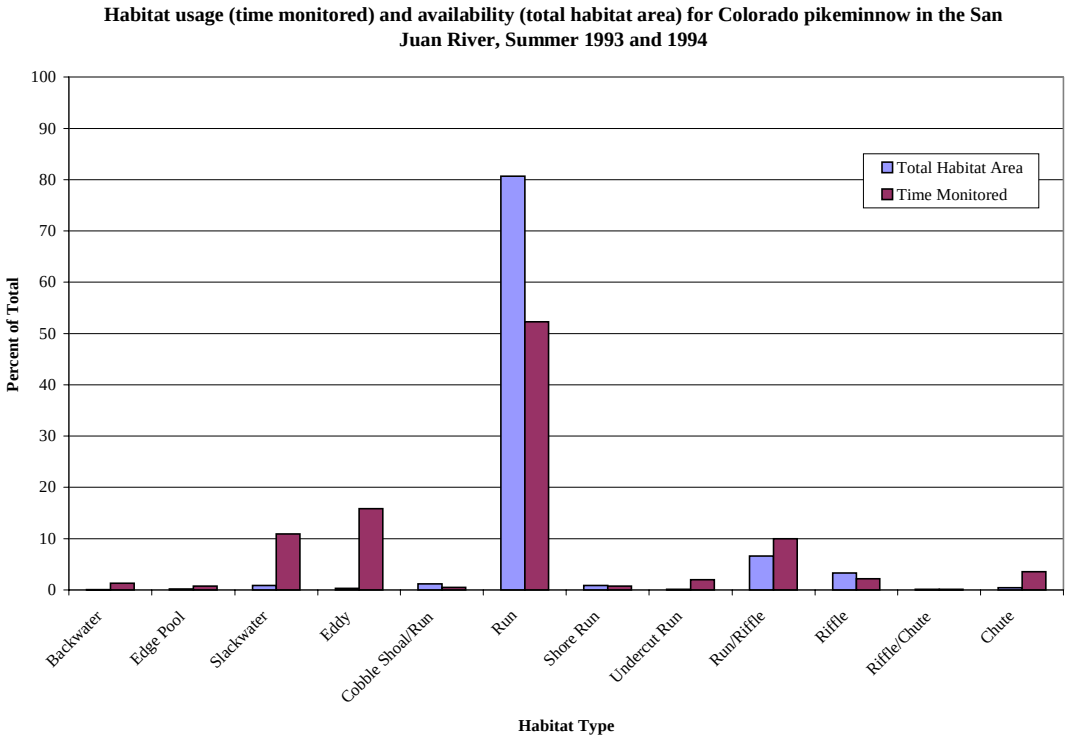
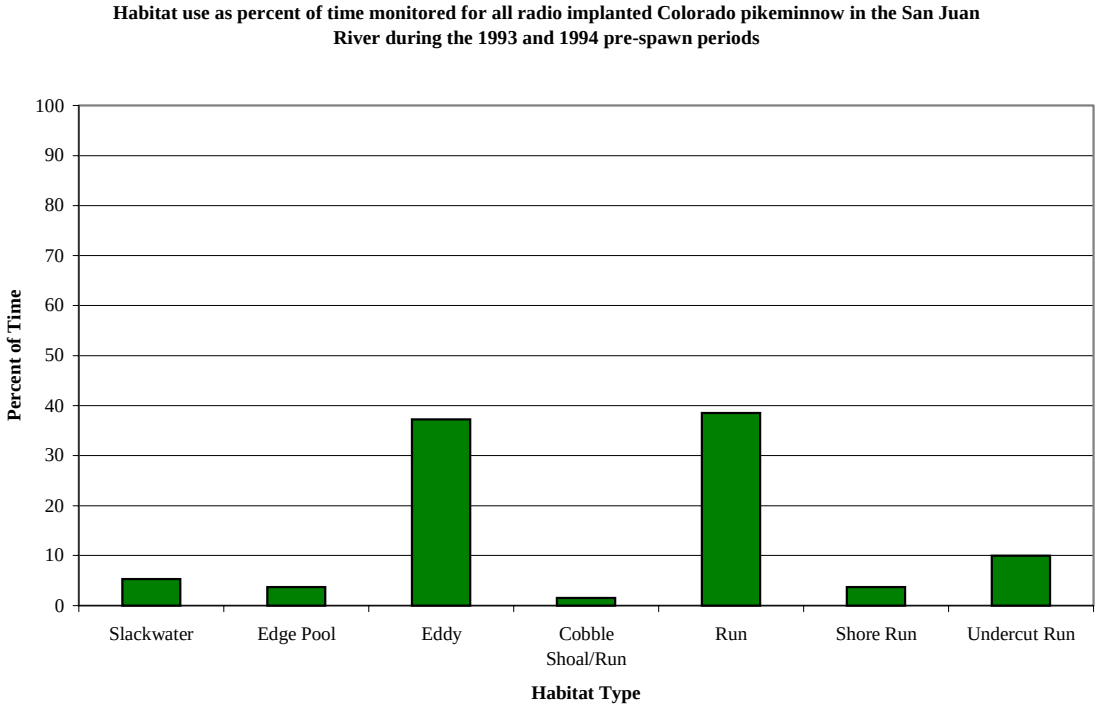


Figure 21. Habitat use as a percent of time monitored during the pre-spawn periods 1993 and 1994.



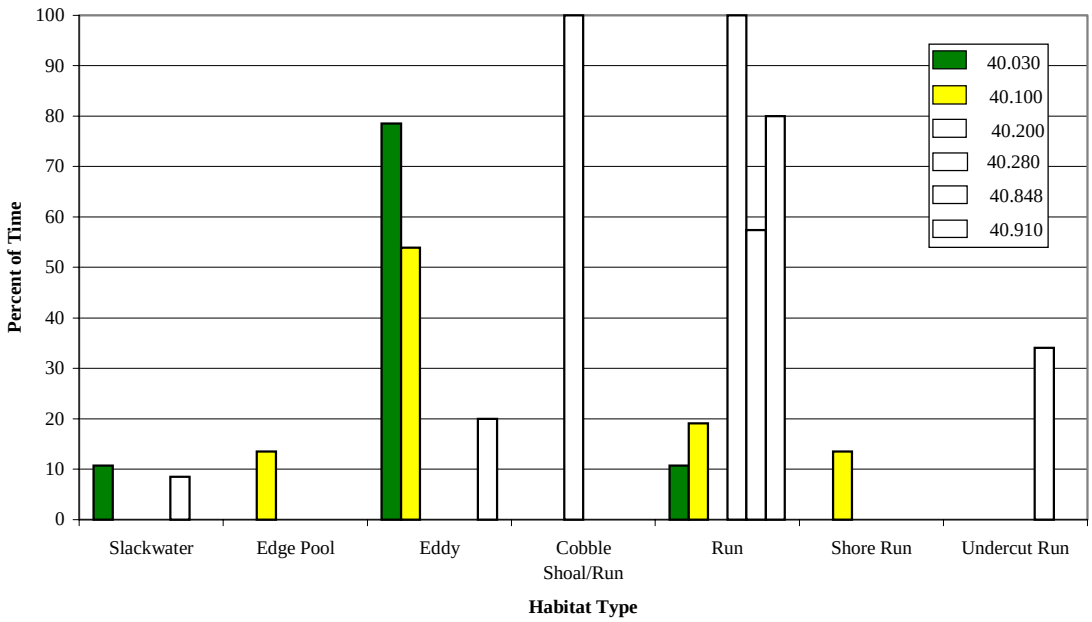
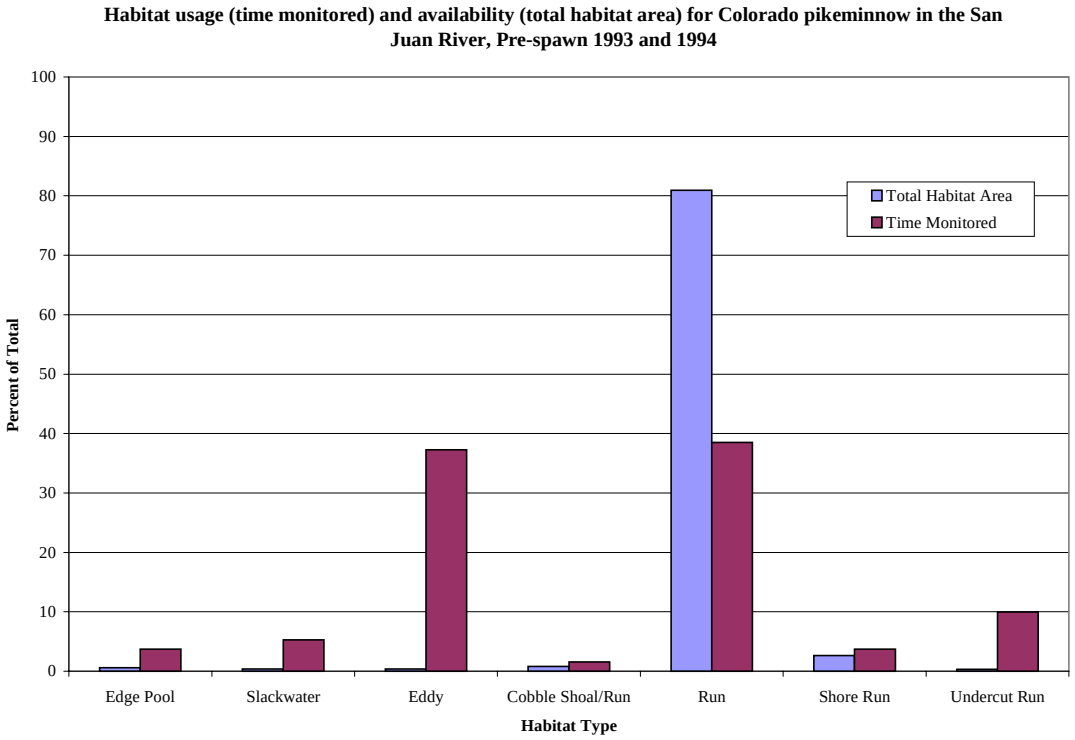


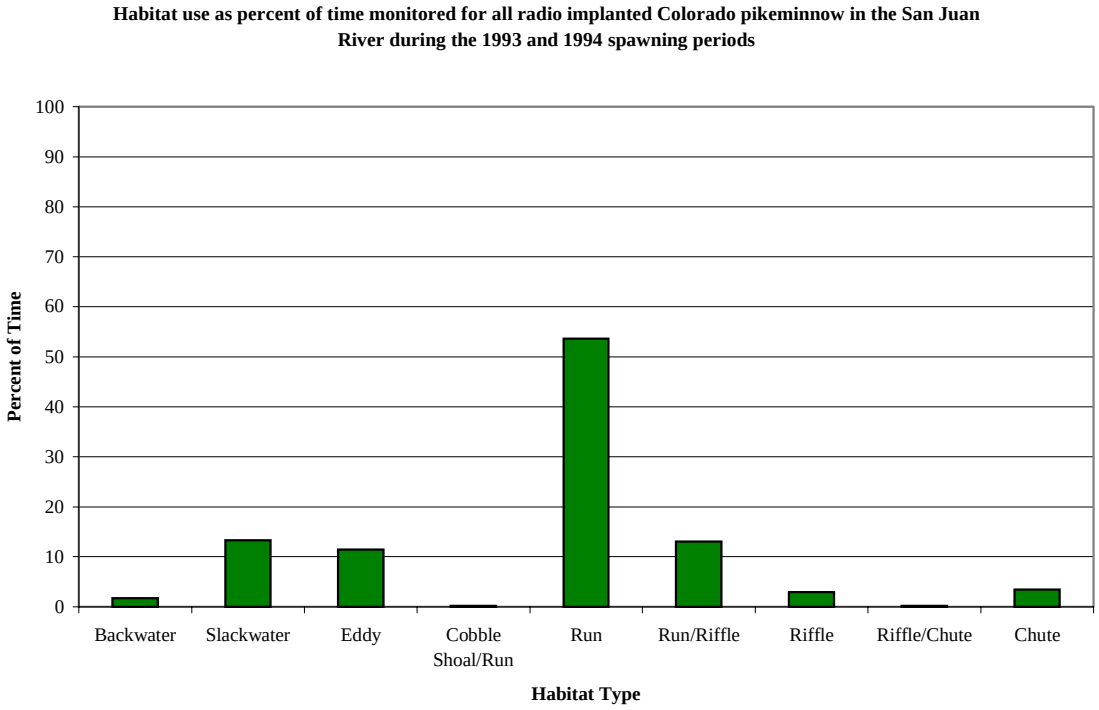
Figure 22. Habitat usage and habitat availability as a percent of total during the pre-spawn period, 1993 and 1994.



Spawning

During both 1993 and 1994 radio implanted pikeminnow used the potential spawning sites at RM 132.0 and RM 131.1. Fish 40.848 used both sites during 1993 and 1994, while fish 40.030 used both in 1994, but only the RM 131.1 site in 1993. All fish that used both spawning sites in one year used the RM 132.0 site first and then moved downstream to the RM 131.1 site. Two fish did not use either spawning site. Fish 40.280 remained near the Mancos River confluence at RM 122.6 during 1994. Fish 40.940 was also located near the Mancos River confluence, but contact with it was lost on 20 June 1994 and when it was finally recontacted it had moved up to RM 134.4. Although fish 40.940 must have traveled by both spawning sites, it was never located by field crews at either spawning site. Run habitat was the predominate habitat used by radio implanted fish (Figure 23). All individual fish used slackwater and run habitat during this period. Slackwater and eddy habitats had the highest selectivity, followed by run/riffle and chute (Figure 24).

Figure 23. Habitat use as a percent of time monitored during the spawning period 1993 and 1994.



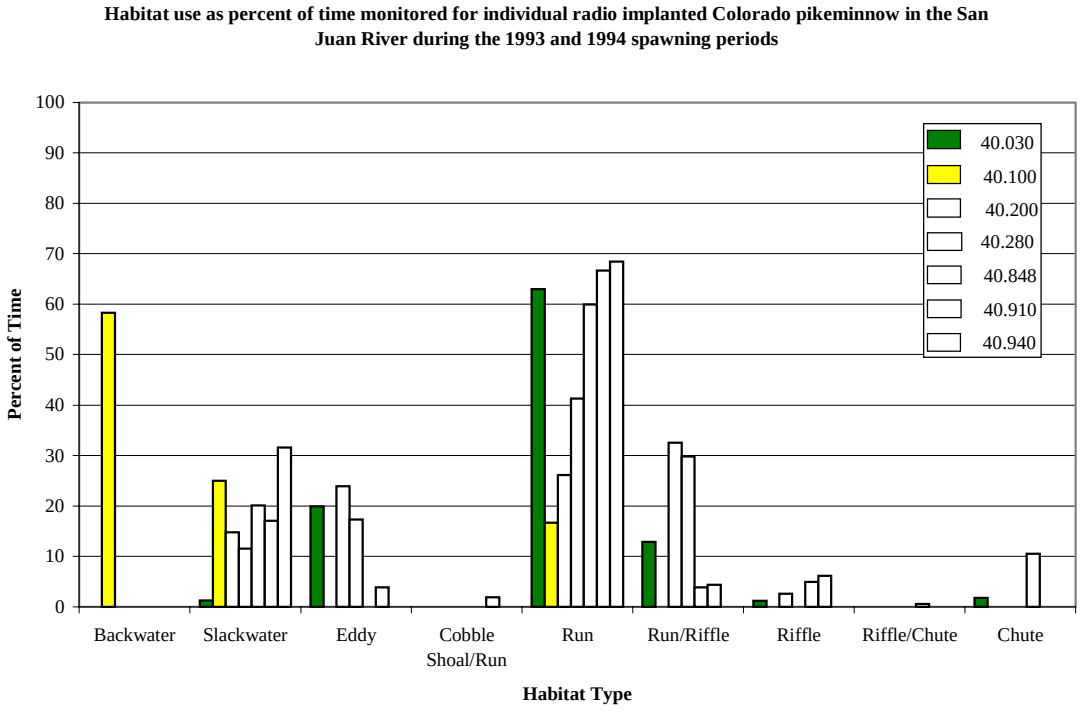
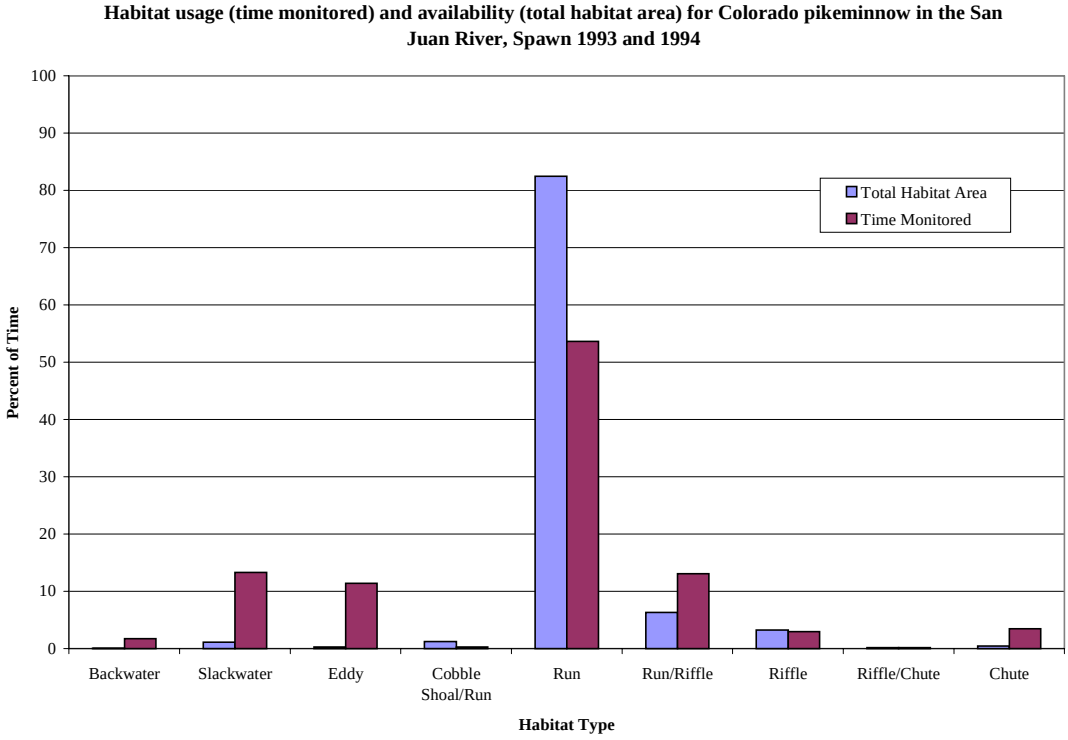


Figure 24. Habitat usage and habitat availability as a percent of total during the spawning period, 1993 and 1994.



1998 – Stocked Adult Colorado Pikeminnow

Hatchery-reared Colorado pikeminnow were intensively radio tracked for 15 days from 23 June – 22 July 1998. Of the 15 stocked Colorado pikeminnow only 7 were located and monitored during the 1998 summer study period (Table 1). Four radio transmitters (40.020, 40.070, 40.110, and 40.130) were recovered during the study period. Fish 40.020, 40.070, 40.110, and 40.130 were alive and monitored before expelling the transmitter or dying. None of the transmitters were recovered in or around any fish remains. Attempts to disturb the fish or recover the transmitter were only performed after the fish had remained in the same exact location for several days of observations. The U.S. Fish and Wildlife Service (Grand Junction, CO) provided the bulk of river mile contact locations for implanted pikeminnow. They provided all contacts from November 1997 through May 1998, as well as contacts from September 1998.

The farthest downstream contact was for fish 40.040 at RM 133.2, while no fish was observed to move upstream of the stocking location (Table 13). Fish 40.110 was located in a small side channel at RM 140.4. All fish demonstrated downstream movement, only fish 40.040 and 40.051 exhibited any upstream movement. Generally, monitored fish

showed little movement during June and July 1998. Fish 40.040 and 40.780 moved the farthest, but only 1.20 and 1.40 mi, respectively.

Table 13. River mile locations for stocked Colorado pikeminnow, June – July 1998. Multiple contact times (24 hr) are in parentheses.

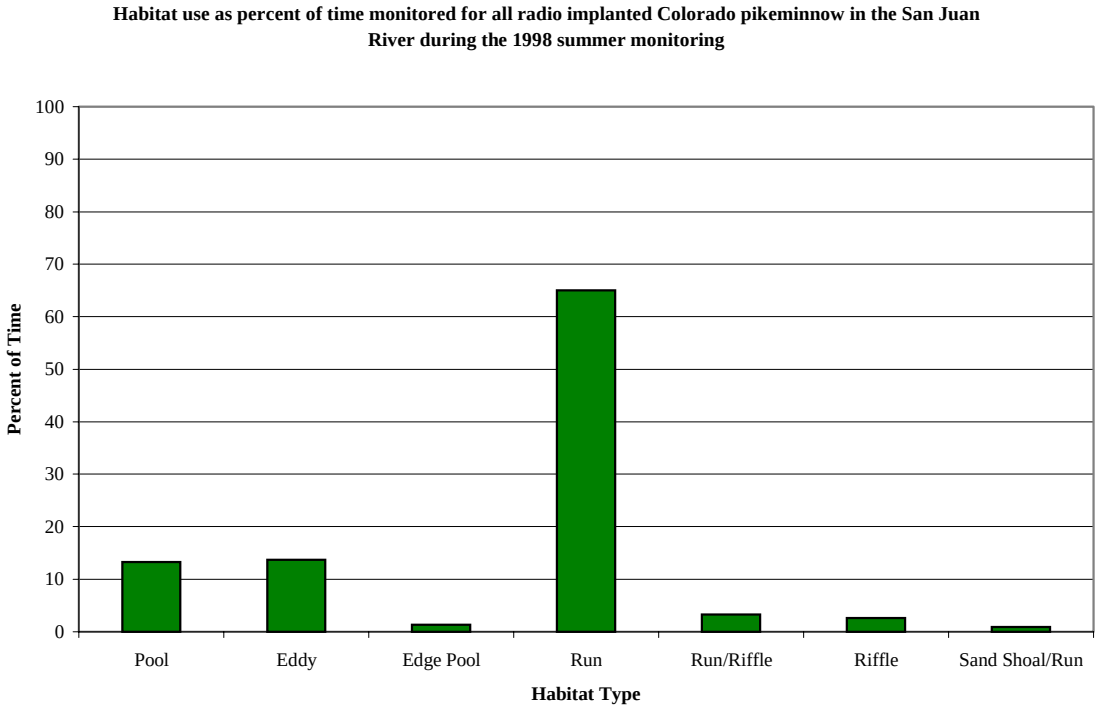
	Fish Frequency						
Date	**40.020**	**40.040**	**40.051**	**40.070**	**40.110**	**40.130**	**40.780**
09/23/97	178.80	178.80	178.80	178.80	178.80	178.80	
09/29/97	171.50	177.30	171.50	177.45	177.70	177.70	
11/18/97		177.40	168.00	177.10			
11/20/97						158.50	
12/11/97					140.50		
02/03/98		177.30					
02/04/98			168.00	176.80			
02/05/98						158.10	
03/31/98		177.30					173.60
04/27/98	141.30				140.40	137.90	
04/28/98				153.70			
04/29/98		177.30	168.60				173.60
05/05/98	141.20				140.10	137.85	
06/15/98		177.30	168.50		140.50	137.85	172.90
06/16/98	140.20			152.80			
6/23/98	140.40				140.40	137.80	
6/24/98				152.80			
6/25/98			168.40				171.80
6/26/98	140.50				140.40	137.80	
7/7/98	140.40				140.40	137.80	
7/8/98		175.60	168.40 (1300)				
7/8/98			168.30 (1415)				
7/9/98			168.40				
7/10/98			168.40				
7/15/98			168.50				170.40
7/16/98		176.50	168.50				
7/17/98			168.50				
7/21/98		176.70	168.50				
7/22/98		176.70 (0930)					
7/22/98		176.60 (1830)					
7/22/98		176.80 (2230)					
09/30/98		133.20					
Movement							
MIN (RM)	140.20	133.20	168.00	152.80	140.10	137.80	170.40
MAX (RM)	178.80	178.80	178.50	178.80	178.80	178.80	173.60
GROSS (mi)	38.60	45.60	10.50	26.00	48.70	41.00	3.20

Table 13 (continued). River mile locations for stocked Colorado pikeminnow, June – July 1998. Multiple contact times (24 hr) are in parentheses.

	Fish Frequency									
Date	**40.030**	**40.060**	**40.080**	**40.090**	**40.100**	**40.120**	**40.140**	**40.490**	**40.600**	**40.611**
09/23/97	178.80	178.80	178.80	178.80	178.80	178.80	178.80		178.80	178.80
09/29/97	177.40	175.10	176.90	173.90	177.45		177.60			178.50
11/18/97	176.60			173.10	170.00					
11/20/97									155.60	
02/04/98										
02/05/98										
03/31/98								177.20		
04/29/98								178.20		
06/15/98										
Movement										
MIN (RM)	176.60	175.10	176.90	173.10	170.00	178.80	177.60	177.20	155.60	178.50
MAX (RM)	178.80	178.80	178.80	178.80	178.80	178.80	178.80	178.20	178.80	178.80
GROSS(mi)	2.20	3.70	1.90	5.70	8.80	0.00	1.20	1.00	23.20	0.30

Radio implanted fish spent over 60% of the total time monitored in run habitat, with eddy and pool habitat being the second and third most used (Figure 25). Four fish (40.020, 40.070, 40.130, 40.780) used run habitat exclusively. Fish 40.110, which was located in a side channel, only used pool habitat. Eddy habitat had the highest selectivity followed by pool habitat (Figure 26). Habitat richness was significantly higher for the spawning period compared to the pre-spawn period (Table 6).

Figure 25. Habitat use as a percent of time monitored during the summer 1998.



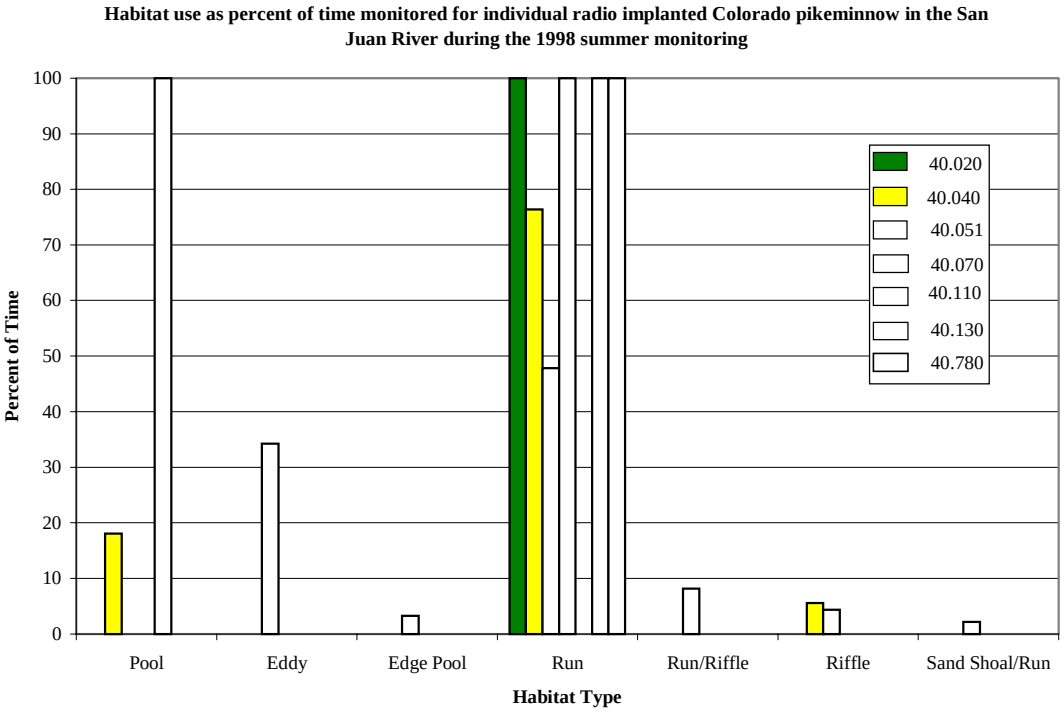
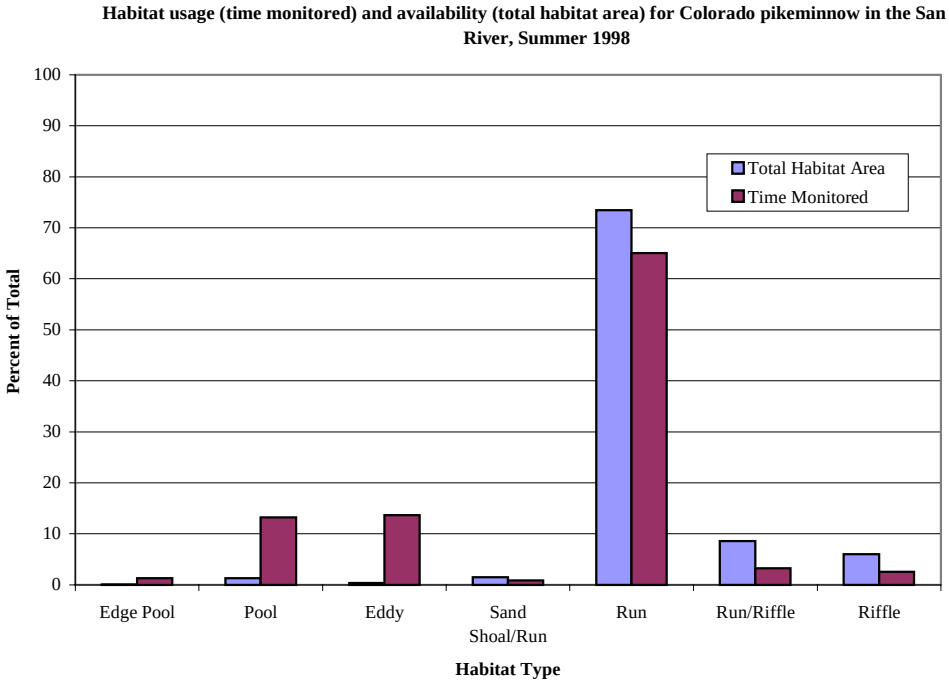


Figure 26. Habitat usage and habitat availability as a percent of total during the summer 1998.



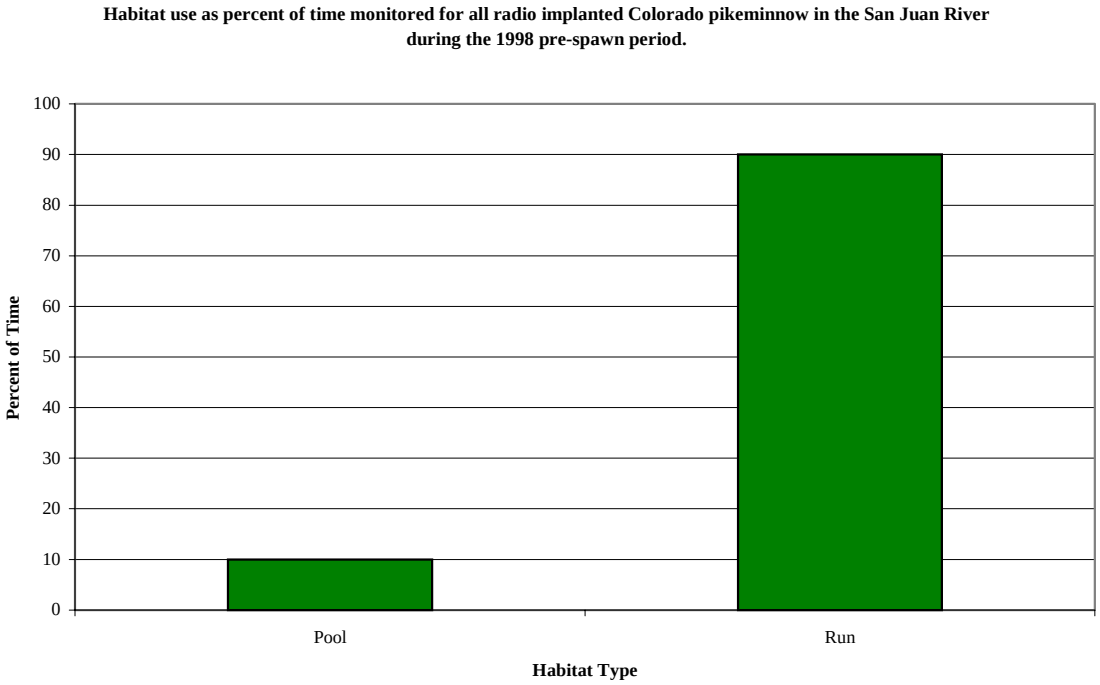
Pre-spawn

One week of monitoring was completed during the last week of June, 1998. All seven fish were contacted, although 40.040 was stranded in a gravel pit near RM 178.5. Run habitat was used almost exclusively during this period (Figures 27 and 28). Only one fish (40.110) used a habitat type besides run.

Spawning

During the spawning period only three fish (40.040, 40.051, and 40.780) were actively monitored due to the recovery of the other four transmitters. Fish 40.040 was slowly moving upstream during this period. On 8 July 1998 it was located at RM 175.6 and on 22 July 1998 it was contacted at RM 176.8 (Table 13). Fish 40.051 was located around RM 168.4, near the Hatch Trading Post. Run habitat was the predominate habitat used,

Figure 27. Habitat use as a percent of time monitored during the pre-spawn period 1998.



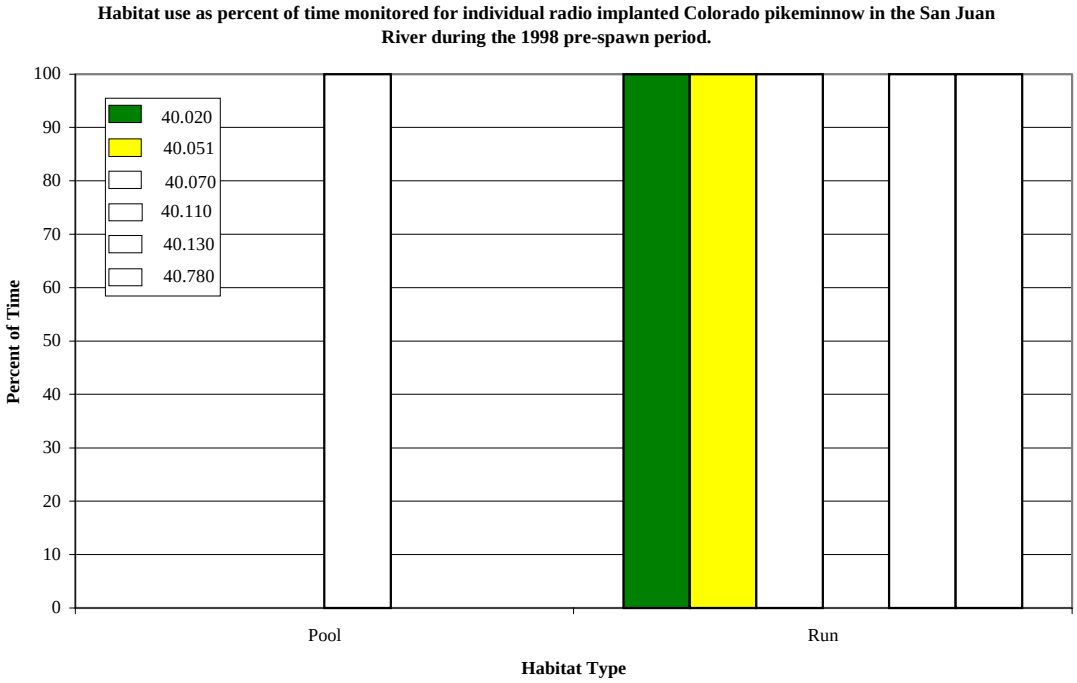
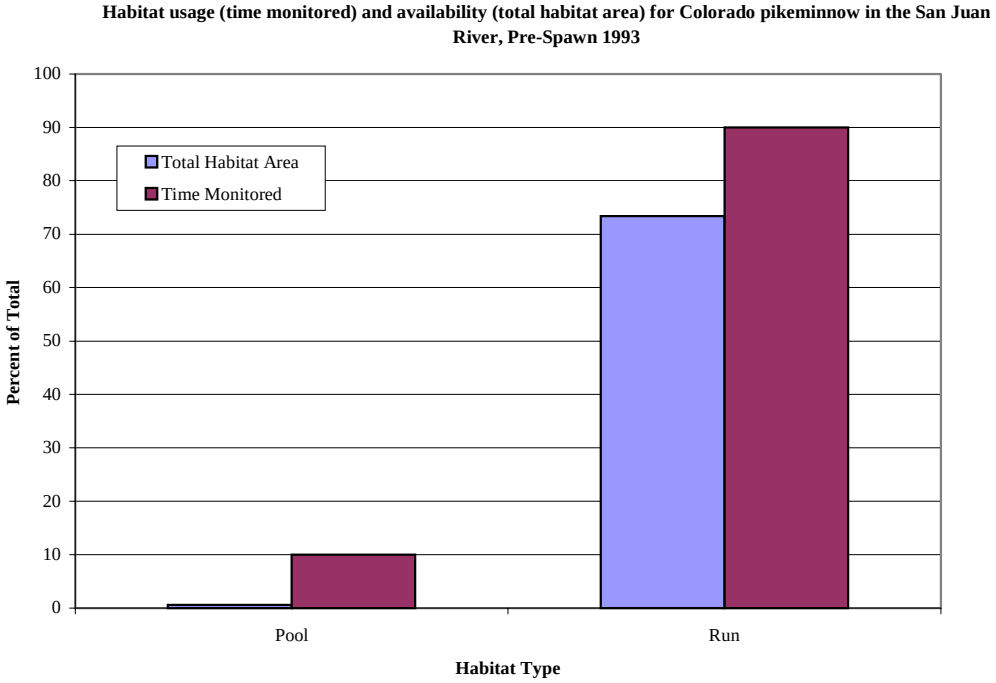


Figure 28. Habitat usage and habitat availability as a percent of total during the pre-spawn period, 1998.

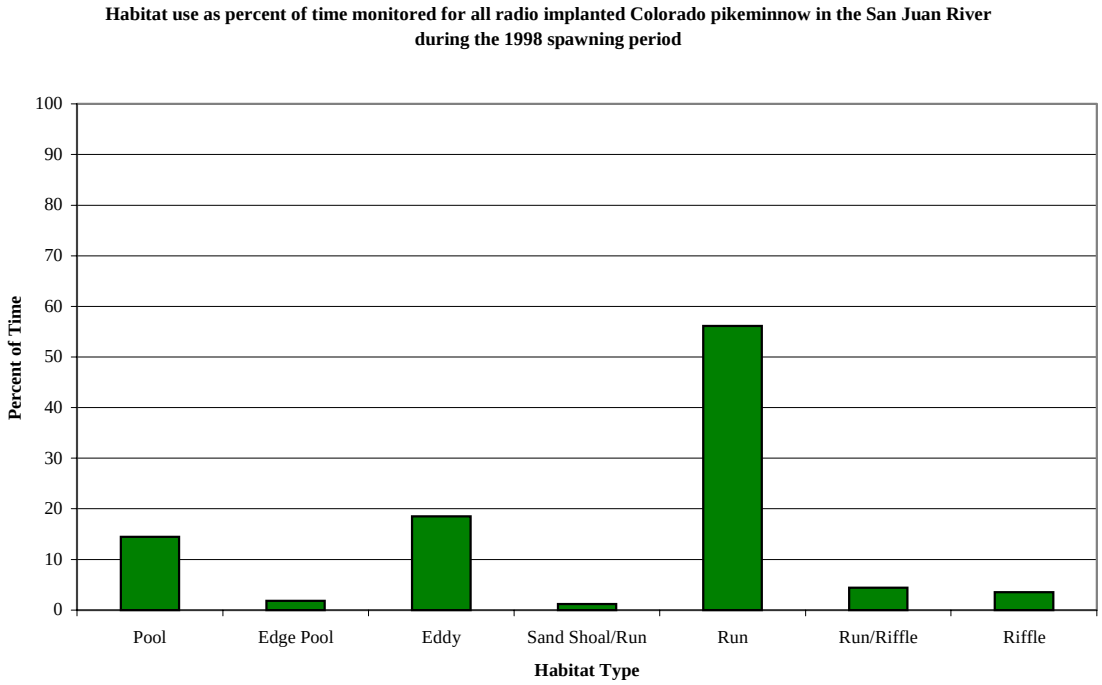


although fish were found in seven different habitat types (Figure 29). Fish 40.020, 40.130, and 40.780 used run habitat exclusively, while fish 40.110 remained in the side channel pool habitat (Figure 29). Fish 40.051 displayed the greatest diversity in habitat use, using six of the seven habitats. During this spawning period, radio implanted Colorado pikeminnow demonstrated a selectivity toward pool and eddy habitats (Figure 30).

River Mile 168.4—Hatch Trading Post

A potential Colorado pikeminnow spawning site was identified at RM 168.4, which is near the Hatch Trading Post (Figure 31). Fish 40.051 was located in this area during the entire 1998 monitoring. This site is physically similar to the RM 132.0 and RM 131.1 spawning areas. All three locations include island, cobble bar, run/riffle or riffle, and resting habitat complexes. On two occasions fish 40.051 exhibited possible spawning type behavior. During a 24 hour observation on 8 July and 9 July 1998 it used a near shore eddy and occasionally moved up into a side channel riffle, remain there for 20 minutes or more, and finally return to the eddy. On 15 July 1998, fish 40.051 moved 0.10 miles upstream into a side channel on river left. It repeated the previous behavior of using an eddy, moving up into a riffle and subsequently returning to the eddy. Eddy depths (two points) were 0.70 and 0.98 m, while riffle depths (two points) were 0.55 and 0.46 m. Due to poor water clarity no visual observation of the fish was possible.

Figure 29. Habitat use as a percent of time monitored during the spawning period 1998.



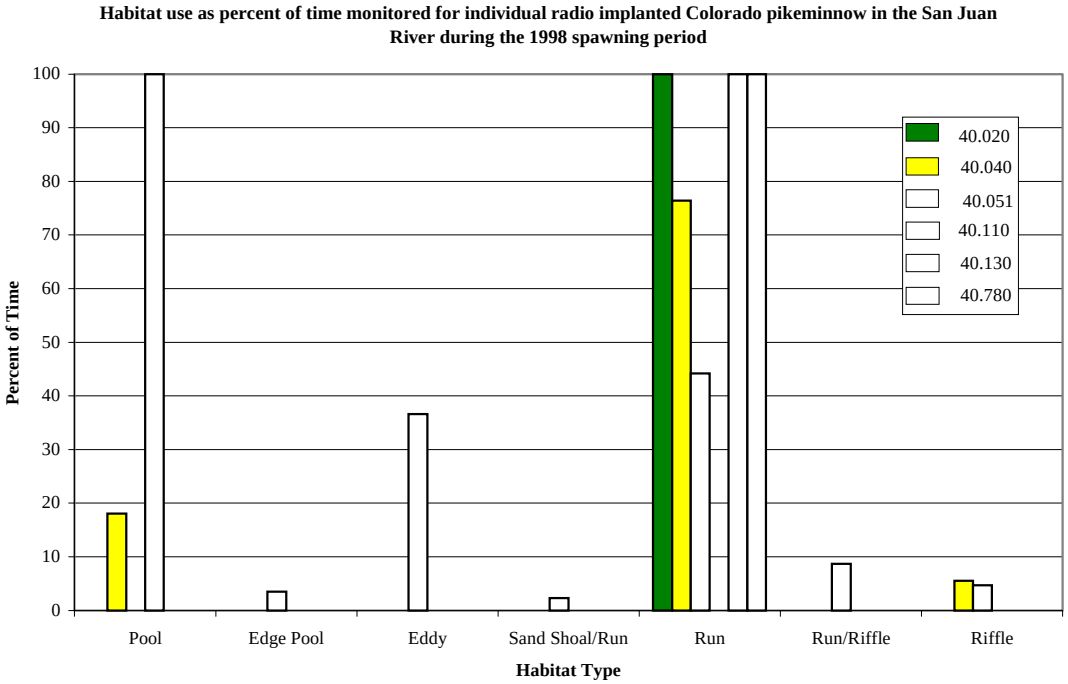


Figure 30. Habitat usage and habitat availability as a percent of total during the spawning period, 1998.

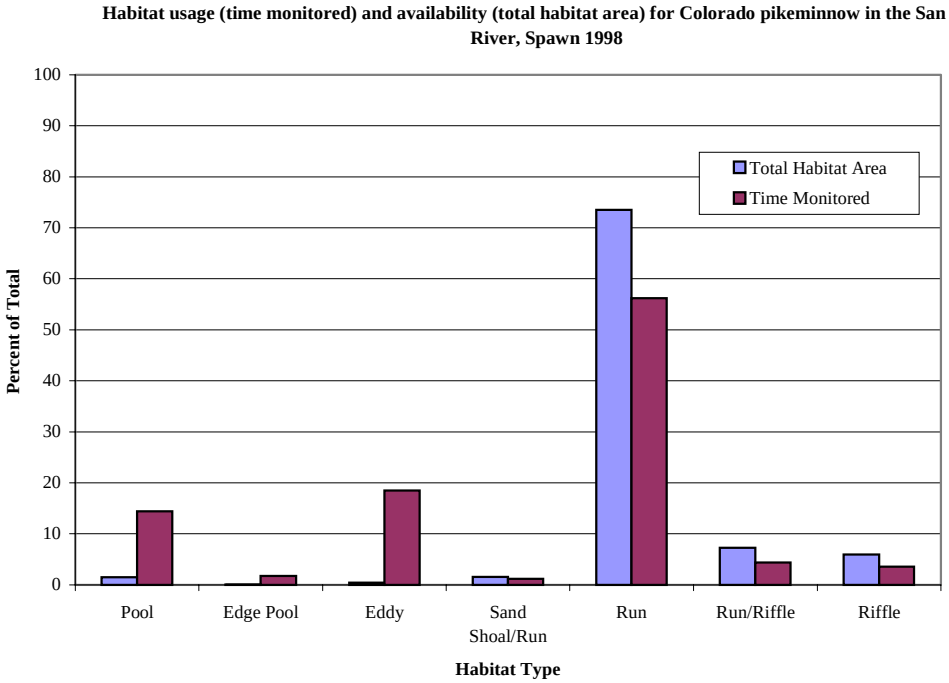
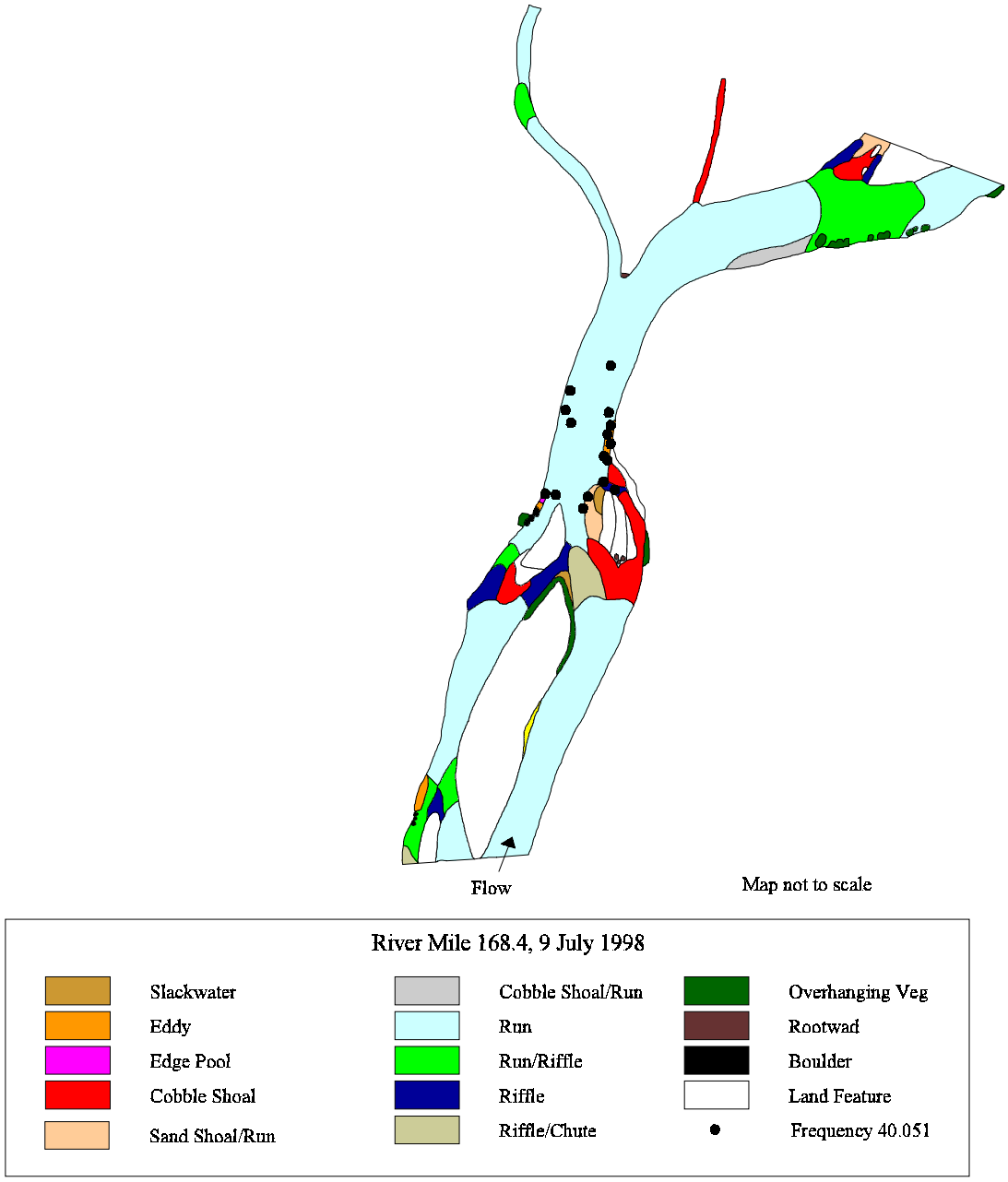


Figure 31. Suspected spawning location 1998.



DISCUSSION

Radio telemetry studies on Colorado pikeminnow provided seasonal habitat use, river reach use, and spawning behavior for San Juan River fish. These studies also identified possible spawning areas. The majority of wild Colorado pikeminnow contacts were between RM 120.0 and RM 142.0. Only one fish was located outside of this range. Ryden and Ahlm (1996) also found Colorado pikeminnow to be concentrated within this section of the San Juan River. Three of the stocked Colorado pikeminnow were also found in this area, although all three of the transmitters were eventually recovered. It is unknown whether the fish expelled the transmitters or died.

There was a high loss of transmitters from stocked fish due to mortality or transmitter expulsion. High rates of mortality and transmitter expulsion have also been documented for other fish species (Summerfelt and Mosier 1984; Chisholm and Hubert 1985; Ryden 1999). All three of these studies used hatchery raised fish. During the 1993 and 1994 monitoring of wild fish neither transmitter expulsion or mortality occurred. Miller and Rees (1997) had similar success in transmitter retention and low mortality with wild Colorado pikeminnow in the Yampa River, Colorado. Wild Colorado pikeminnow may be able to endure the required surgery and placement of a transmitter in the abdominal cavity better than hatchery raised individuals.

Generally, stocked Colorado pikeminnow did not behave like the wild fish monitored in 1993 and 1994. Only the stocked Colorado pikeminnow 40.051 exhibited behaviors and habitat use similar to a wild fish. After release, only two (40.040 and 40.051) stocked Colorado pikeminnow exhibited any upstream downstream movement. These fish only moved upstream a short distance (0.3 and 0.5 mi, respectively). All other monitored fish only displayed downstream movement, which was probably the result of poor health of the fish. Tyus and McAda (1984) noted a steady downstream movement associated with Colorado pikeminnow known to be in poor condition. At the conclusion of the intensive monitoring period in July 1998 only three of the fifteen stocked pikeminnow were alive and carrying transmitters. During a September 1998 survey, only one pikeminnow could be located by U.S. Fish and Wildlife Service (Grand Junction, CO) personnel.

Studies on other upper basin rivers have found that Colorado pikeminnow habitat use varies seasonally (Holden and Wick 1982; Wick et al. 1983; Tyus and McAda 1984; Osmundson and Kaeding 1991; Osmundson et al. 1995). The results of this study further substantiate those previous findings. Habitat use also varies between river systems (Tyus and McAda 1984). Not only are the river systems unique but habitat type designations are often subjective decisions made by researchers. This creates some difficulty in comparing specific habitat type usage between other river systems and other studies.

During the pre-spawn period, Colorado pikeminnow use predominately slower velocity habitats such as runs, eddies, undercut runs, slackwaters, and edge pools. Four of seven radio implanted wild Colorado pikeminnow, including fish 40.030 in both 1993 and 1994, used the area around RM 122.6 (Mancos River mouth). Ryden and Ahlm (1996)

also documented Colorado pikeminnow congregating near the mouth of the Mancos River before the spawning period. Many authors have reported high use of backwater habitats during run-off flows in other upper basin tributaries (Osmundson and Kaeding 1989; Tyus 1990; Wick et al. 1983). In the San Juan River, the pre-spawn period usually corresponds to the ascending limb of spring runoff. The lack of backwater use by Colorado pikeminnow in the San Juan River may simply be a function of lack of habitat. The channel morphology of the San Juan River does not allow extensive formation of backwaters. Bliesner and Lamarra (1995) reported that during June high flows the amount of backwater, embayment, pool, and eddy habitat was the lowest compared to other periods. The area around the Mancos River mouth functions much as a backwater habitat, offering Colorado pikeminnow refuge from high velocities and low temperatures in the main channel.

Three potential spawning sites were identified, two in the "Mixer" (RM 131.1, RM 132.0) and one at Hatch Trading Post (RM 168.4). Telemetry and visual observation data from 1993 and 1994 indicate possible spawning aggregations of fish at RM 132.0 and RM 131.1. Repeated use of these sites suggests that Colorado pikeminnow in the San Juan River, like pikeminnow in the Green, Yampa and Colorado Rivers, show fidelity toward specific spawning sites. Three wild Colorado pikeminnow were documented using both potential spawning sites in the "Mixer" during a single spawning period. The three fish (one in 1993, one in 1994, and one in both years) were present at the RM 132.0 site for 2 or 3 days and subsequently moved down to the RM 131.1. This repeated, ordered use of spawning the potential spawning sites at RM 131.1 and RM 132.0 is possibly an unique feature of this population. A repeated, ordered use of spawning sites has not been reported for any other Colorado pikeminnow populations. This behavior could be in response to the effects of decreasing flows on the sites. The upstream site may have better habitat at higher flows, and conversely, the downstream site may function better at lower flows. The third potential spawning location at RM 168.4 was located during the 1998 monitoring of stocked pikeminnow. The island complex at RM 168.4 was physically similar to physical characteristics. This site was previously identified in habitats surveys as having the potential to be a spawning location. While no other radio implanted pikeminnow used the area during the study, there may have been stocked or wild fish without radio transmitters present, which may have caused the one implanted fish to remain in the area. The stocked pikeminnow's behavior was very similar to the spawning behaviors exhibited by wild fish in 1993 and 1994. Larval fish sampling was conducted on 22 July 1998 by the University of New Mexico (Albuquerque, NM) downstream of the RM 168.4 area. Marsh (1985) the incubation period for pikeminnow eggs held at 20^{o}C was 3-5 days. The larval fish sampling may have been to late to capture larval pikeminnow because the possible spawning occurred on 9 July and 16 July 1998.

This site is well upstream of the "Mixer" area. Stocked, hatchery-reared Colorado pikeminnow did not migrate downstream to either of the potential spawning sites in the "Mixer". The upstream (RM 178.8) stocking location, non-imprinting of stocked fish, as well as poor health may have contributed to the lack of movement to the downstream spawning sites.

During the spawning period, higher velocity habitats such as riffles, riffle/chutes and chutes are utilized. The use of these habitats is likely due to the velocities and substrates required for successful spawning. General spawning behaviors of Colorado pikeminnow in the San Juan River appear to include activities such as: the fish moving from low velocity habitats, like eddies, into the higher velocity habitats run/riffle, riffle, and chute and finally move back into the resting habitat. This observed behavior is similar to Colorado pikeminnow spawning behaviors reported by other researchers (Miller et al. 1982). Colorado pikeminnow used run habitats as possible resting/foraging areas during the spawning time.

After the post-spawn dispersal, Colorado pikeminnow move into simpler habitat complexes. The use of run habitat is much more widespread than in the previous pre-spawn and spawning periods. This behavior has been noted in other upper basin populations (Osmundson et al. 1995). Fall and winter behavior seemed to be similar for Colorado pikeminnow as shown in other rivers, with fish mainly using main channel pools or runs during these periods (Osmundson et al. 1995). Activity tended to peak during the middle of the day. This behavior is similar to that exhibited by razorback suckers in the San Juan River (Ryden, 1999)

The fragmentation of populations due to the creation of impassable dams and diversions is one reason the Colorado pikeminnow has declined from historic levels. The San Juan River has many diversions used to divert river water for irrigation and municipal purposes. This study documented the first confirmed movement of a Colorado pikeminnow upstream through Cudei diversion. This event showed that Cudei diversion is passable by Colorado pikeminnow. The movement of a Colorado pikeminnow through Cudei diversion occurred during the 1994 study year, when fish 40.940 was located just upstream of the earth and rock diversion structure on 27 July 1994. Discharge at the USGS Shiprock gage ranged from 1920 cfs on 17 July 1994 (last contact below Cudei diversion) to 820 cfs on 27 July 1994 (first contact above Cudei diversion).

The methodology of Osmundson et al. (1995) and Ryden (1999) was not used for determined habitat selectivity because there can be some bias associated with those calculations. The "aggregate percent method" (Swanson et al. 1974) may offset a lot of the bias associated with using small data sets, but when data sets are extremely low, bias may still become evident. The influence of one pikeminnow's habitat use can skew the selectivity to that particular habitat. For example, one pikeminnow (40.100) spent nearly 60% of its time monitored in backwater habitats during the spawning period. But that fish was only monitored for three hours of one day during that period. Calculating selectivity using the method of Osmundson et al. (1995) and Ryden (1999) indicated that backwater habitat was the most preferred habitat, which does not appear to be the case by visual examination of usage versus availability. Their methodology would have been credible had more monitored fish and contact data been available.

CONCLUSIONS

- Habitat use during the suspected spawning period is concentrated in areas of very diverse habitats with numerous habitat types present. These areas are located in conjunction with complex bar and island systems that have many different habitat types in a small local area. Main features present at the suspected spawning areas include eddies or pools as resting habitat located in close proximity to chutes or steep riffles with very loose cobble substrate.

- Two (RM 131.1 and RM 132.0) potential spawning locations were identified for wild fish and one (RM 168.4) for stocked Colorado pikeminnow. One of those locations had a documented visual sighting of two paired Colorado pikeminnow, male and female, that were implanted with radio transmitters. The potential sites at RM 131.1 and RM 132.0 were used during both 1993 and 1994 and were used in the same sequence each year. The uppermost site at RM 132.0 was used first followed by the RM 131.1 site.

- The use of various habitat types is related to the flow regime as well as life history traits of the Colorado pikeminnow. The pre-spawn time period is during the ascending limb of runoff, which floods local embayments, tributary mouths and secondary channels that provide Colorado pikeminnow staging habitat. During the descending limb of runoff, the habitat complexes for spawning become available, provided sufficient cleaning is done during the peak runoff. These habitats appear to be used for varying lengths of time depending on the suitability of velocities in chute/riffle habitats and the embeddedness of cobble substrate.

- Maintaining habitat richness is an important component of maintaining the potential spawning habitats for the fish. Highest habitat use during the spawning periods was in the area of highest habitat richness. Flows that develop and maintain complex habitats over the long term should provide the physical characteristics necessary to provide the spawning habitat.

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